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Problems and Organization Needs of the Engineering College Research Association

By W. R. WOOLRICH

President of the Engineering College Research Association, and Dean of the College of Engineering of The University of Texas

EDITOR'S NOTE—This article by Dean Woolrich is one of the series describing the responsibilities, objectives and needs of the ECRA and the Administrative Division of S.P.E.E. which led to the appointment of the Committee on Revision of the Constitution and By-Laws. The series of articles will serve as a background for the recommendations on revision which will be placed before the Society under the directive of the Council.

The Engineering College Research Association was organized in 1942 with four explicit objectives. First, it was to be an agency to assist in organizing the research facilities of engineering colleges in the prosecution and promotion of engineering research. Second, it was to assist in organizing these research facilities to improve processes affecting industry, public works, public health, and future conservation and development of natural resources. Third, it was organized to serve as a developing and coordinating industrial and scientific agency for furthering advanced study in the colleges of engineering of the United States. And fourth, it was organized to collaborate with other associations and with the Federal Government in the interest of maximum utilization and development of the engineering and scientific facilities of the nation, thus to achieve a maximum of coordination with a minimum of duplication of effort.

For many years the Committee on Engineering Research of the Society for the Promotion of Engineering Education had successfully carried on annual sessions on engineering research and had held several forums and symposiums on engineering research. Paralleling this activity, the Land-Grant College Association had carried on effectively an organization within its own group to coordinate and encourage engineering college research. A similar group representing the engineering colleges of the separated state universities had maintained a loosely organized but well coordinated interchange of information on engineering research. Again, there were a considerable number of the engineering colleges of the metropolitan districts that had maintained some interchange of information and coordination as between their own members in effecting the research of their respective institutions.

A joint committee of representatives of the land-grant colleges, the state uni-

versities, and the endowed colleges and universities had discussed at length with the Council of the Society for the Promotion of Engineering Education the possibility of setting up a more active research body under the constitution of the Society for the Promotion of Engineering Education. After much consideration, the Council of the Society indicated that it did not believe the objectives in which the research groups were vitally interested could legally be carried on under the Society for the Promotion of Engineering Education, and it was suggested that a separate organization be set up to carry on the research activities, this new organization to be parallel and coordinate with the Society for the Promotion of Engineering Education. Thus, during a meeting of the Society for the Promotion of Engineering Education in Chicago in October, 1942, a separate place was made on the agenda in cooperation with the S.P.E.E. for an organization meeting to set up the new college research association. On October 26, 1942, this meeting was called in Thorne Hall of Northwestern University, its name adopted as the Engineering College Research Association, and its constitution proposed and accepted.

The admission requirements for the Engineering College Research Association were made somewhat selective, since it was believed that the members should represent only those engineering college research organizations that were real going concerns in research. The membership was therefore limited to those institutions which had one or more curricula accredited by the Engineers' Council for Professional Development and which could show that research activity had existed in their respective institutions for at least three years and that at least $10,000 had been expended on active research within the three-year period prior to admission. It was further agreed that a member institution must maintain a high record of performance in engineering research to remain in good standing as an active member.

Probably the greatest need that was filled by separate organization of the Engineering College Research Association was the autonomy thereby received in proceeding to press matters of great importance before legislative and other federal groups. It was this right to appear before Congressional committees and legislative groups that had not been permissible under the Society for the Promotion of Engineering Education and that under the new organization gave it a most active field of endeavor.

The extensive and most productive activities of the three major committees of the Engineering College Research Association, namely, the Committee on Federal Legislation, the Committee on Relations with Federal Research Agencies, and the Editorial Board, need a high degree of autonomy to work successfully in their respective fields.

The question is sometimes posed, "Why does the engineering college research group need this freedom of action as at present provided in its constitution?" The realistic answer lies in the excellent and effective work performed by the two committees of the Engineering College Research Association whose charge it has been to represent the engineering research bureaus, divisions, and experiment stations in recent war and post-war activities of the Federal Government. With emergency federal legislation and directives pointed at establishing controls and allocation of scientific and engineering

research, the authority to speak with firmness and decision was most essential to the Committee on Federal Legislation and the Committee on Relations with Federal Research Agencies.

Their representation of the engineering research agencies of the engineering colleges will be set down in our history as one of the most constructive and protective jobs done by any group of engineering educators and administrators in the present national readjustment of scientific endeavor. Had these two committees not been present and most active at the critical moments in Washington and the contiguous territory during this re-orientation of federal emphasis on research, there is no question but that engineering research would have been submerged by the active and effective work of zealous exponents of research in other fields.

To effect such a contribution to engineering research, power and authority to speak and act without undue delay yet with judicial certainty was most essential. It brought results for which the engineering profession can be grateful.

Again, the principal accusation made against the research activities of the engineering colleges over the past four decades has been their slowness and languor in approaching critically important problems. Much of this criticism was justified, as engineering research was too often envisioned by the institutional director as a luxury that should receive long and thoughtful study. The outstanding and epochal discoveries and accomplishments of the engineers and physicists who were recruited from the teaching personnel of our American universities during the past five years has demonstrated that thoughtful study can be accomplished without years of pondering reverie. The operational organization of the Engineering College Research Association, as the contact agency of the research divisions of the engineering colleges, has demonstrated this same ability to meet emergency measures with discretion and good judgment and thus to reflect the emerging attitude of the modern order of engineering research as represented in the sixty-seven active member institutions of the Engineering College Research Association.

During the three years of its existence, the Engineering College Research Association has published two complete directories of the member institutions and their principal fields of research. These have been placed in all of the larger libraries of the United States and with a large number of the more active industrial organizations of the nation. Also, a substantial number of these directories have been placed in the hands of the active research agencies of the Federal Government. This is probably one of the first times in the history of the United States that a comprehensive directory of the research activities of the engineering colleges has been made possible. The results have been most gratifying in that repeated requests have come from industries and the Federal Government for a continuation of this type of service, which is of value both to the engineering colleges and to the industrial life of our nation.

At the present time the officers and directors of the Engineering College Research Association find it most desirable to hold the annual meeting just prior to and in the same city with the annual meeting of the Society for the Promotion of Engineering Education. By this close cooperation with the Society for the Promotion of Engineering

Education, a strengthening of both organizations has been effected.

During the past eighteen months a mutual effort has been made on the part of the Engineering College Research Association and the Society for the Promotion of Engineering Education to create one organization that could encompass the objectives of both. This merger proposal came after there had been some evidences that the Administrative Division of the Society for the Promotion of Engineering Education had many items more in common with the activities of the Engineering College Research Association than with its parent organization. Out of these suggestions there came the definite belief that if the Engineering College Research Association could retain its autonomy and work with the Administrative Division of S.P.E.E. in a coordinated and correlated program, probably the entire parent organization, as well as its Administrative Division, and the E.C.R.A. would be equally benefited.

The proposed constitution of the American Society for Engineering Education has anticipated these needs of the Administrative Division of the Society for the Promotion of Engineering Education and of the Engineering College Research Association and has set forth a policy, procedure, and administrative organization that will give such freedom of action.

The present Engineering College Research Association requires a separate membership fee from that of the Society for the Promotion of Engineering Education. The proposed constitution of the American Society for Engineering Education would make it possible to offer to the universities and engineering colleges of the United States and Canada one institutional membership that would cover the activities now pursued by the Society for the Promotion of Engineering Education and the Engineering College Research Association.

It is the conviction of the official family of the Engineering College Research Association that the organization plans for consolidation should be mutually creative of new activities for both the Society for the Promotion of Engineering Education and the Engineering College Research Association. To this end, the proposed constitution of the American Society for Engineering Education has been designed to inspire increased activity in all the component parts of the organization.

If this combining of the two organizations is successfully consummated, it will be one of the first demonstrations in the engineering world of a bringing together of two engineering organizations under one membership fee. Up to the present time the trend in the United States has been the division and redivision of engineering activities so that many of us today are supporting four and five different engineering organizations that might have been successfully carried on under one association had our forefathers been somewhat more farsighted in their administrative planning and in their management of their respective membership groups.

Today the Engineering College Research Association, though only in existence three years, has developed a maturity far beyond its years because it was formed in the midst of a national and international crisis in which science and engineering were to make the greatest contribution of all the professions. In its success, it is not unmind-

ful of its great debt to its parent organization, the Society for the Promotion of Engineering Education, and if through a mutually acceptable joint organization, such as the proposed American Society for Engineering Education, it can proceed with its established effectiveness and discretion and with its existing degree of autonomy, it will gladly join in perfecting a stronger and greater engineering fraternity that can speak with one voice for engineering education and research.

Do We Really Need Engineers and Scientists?

By ALLAN R. CULLIMORE

President, Newark College of Engineering

There is a general agreement among those who have studied the question carefully and who possess competency that we of the United States face a critical shortage of engineers and scientists. The need is so great that this shortage will certainly effect not only the internal economy of the country, but will seriously impair the United States as a world power by limiting its capacity to produce and to supply world markets.

This article was written primarily with the idea of exploring some of the factors which enter into this problem in a qualitative, rather than a quantitative way. In the meeting of it, there must be considered the deficit which we face; the capacity of the engineering colleges to train men to meet the deficit; but more particularly at the moment, we must get some general idea of the part which the veteran plays in the whole situation. These men are coming back in great numbers. They offer perhaps, at least superficially, the easiest solution for the problem. Perhaps some indication as to the amount of this load would be of value to the colleges who will have to meet, at least temporarily, a greatly increased load in the first year.

In thinking this problem through, it is well to remember that as an overall national policy with respect to the position of this country in a military way, we must guarantee that we have a sufficient number of technological men and scientists to implement whatever steps are necessary to maintain the position which we have assumed in the international picture.

If we look for a moment at the situation with respect to the needs, we will find that we have been building up a deficit of engineers and technical personnel since the year 1941. Early in 1942 the policy of drawing men into the service very rapidly cut down the number of engineering graduates, and in 1945 a current deficiency of approximately 20,000 engineers resulted. The earliest possible date for graduating sufficient engineers to meet the demand of the current year would be about 1949 or 1950, and it is estimated that a total of about 20,000 engineers will have to be graduated in 1949 if we are to meet the current demands of that year. Roughly speaking, the minimum deficiency which we could base on statistical evidence would be somewhere in the neighborhood of 50,000 engineers in 1949. It is easy to arrive at numbers with more significant figures, but the precision is so low that it would seem wise to use a round number of 50,000 as an absolute rock bottom figure, based on the assumption that post-war needs for engineers will parallel the pre-war needs.

With this more or less factual estimate as a basis, it would seem wise to superimpose certain estimates which

can be based properly upon the ratio of the needs of engineers in post-war years in various industries as compared with pre-war years. In many industries the feeling is that more engineers will be needed in research and development. In other industries, more engineers—technical men—will be needed, particularly in the lines of distribution, with special emphasis on the need in foreign countries—in foreign markets. The averages seem to arrange themselves somewhat after this fashion: The smaller companies to find the greatest need for increased engineering personnel; the medium sized companies less; and perhaps the larger companies the least. These estimates are spread over a very wide range—from 200 per cent in the smaller companies to 50 per cent increase in some of the larger ones.

On the basis of all these estimates, which are matters of expert opinion on the part of competent observers, indications are that, based upon opinions re-enforced by statistics, the deficit of engineers in 1950 would vary from an absolute minimum of say 75,000 to a maximum in the neighborhood of 150,000. These figures, taking into account all the factors of the situation, would seem to be about as precise as we could hope to get.

Let us consider for just a moment from a quantitative standpoint what we can hope to do with respect to offsetting the estimated deficits by the training of veterans and ex-servicemen. This will, of course, depend very much upon the number of men discharged in any one given year. Looking at the situation from the best possible angle —that is, the angle of training the largest number of men possible from the armed forces who would take their places as graduate engineers—we would have in 1946 a total of 3,000 rising to somewhere around 40,000 in 1949 and 65,000 in 1950. This again assumes that selective service will end before September 1, 1946, and depends, as we said, upon other imponderable factors which are not capable of exact solution.

Let us consider further the capacities of the engineering colleges with respect to the veteran load. It is comparatively simple to deduce certain figures indicating the over-all load; and from other information gained from the armed forces it is comparatively simple to arrive at figures indicating the number of men who will enter professional, technological colleges. Suffice it to say that these figures indicate a considerable load, but not an overwhelming one. In order to meet this load there are certain facilities available, and certain factors enter into the question which would tend to lighten the load—perhaps to put it better—would indicate certain points at which this load was heaviest and give us some information upon which to base a procedure to meet the problem.

Assuming that a certain number of men were planning for schooling, the most important single factor entering the situation is probably that of the number of jobs available and the general wage level. If jobs are plentiful the veterans will take them. If they are not plentiful, or if the wage level is low, it will generally be true that the veterans will take up full-time professional academic work. At any rate, the economic situation will be, at least in the opinion of the writer, the most important single factor in the educational problem.

No matter what the situation may be, it is nevertheless true that about one-half of the students wishing en-

trance or applying for entrance in a first-class professional school are rejected because of educational deficiencies or because of deficiencies in aptitudes and attitudes. The effect of this factor on college enrollment is self-evident.

The marital status of the enlisted men is of tremendous importance in appraising the number who will resume full-time school. *"Of the white enlisted men planning to resume full-time school, 93 per cent were single, more than 90 per cent were under 25 years of age, and 90 per cent had the formal education required for entering or resuming college level study." This means that, practically speaking, we would have very few men over 25 years of age in full-time college, and very few unless they were single and unless they already possessed the training necessary for entrance. All these factors would tend to cut very heavily into the estimated college enrollment.

Having the same effect, but having to do particularly with the facilities available, the following factors would seem to be extremely important.

Technical colleges in the United States are at present graduating about 10 per cent of the number of students usually graduated. While the *registration* in colleges of engineering is considerably higher than this, there is at the present time, and will be so long as Selective Service or Universal Military Training takes these boys at 18, a relatively small number of graduates from these schools, which indicates a considerable potential capacity. Another very important factor has to do with the manner in which these students enter. Great numbers are entering in the freshman year; very few, so far, in the upper years.

This number will increase until the bulk of the soldiers have come back, and the effect on the college picture will be a wave whose crest has not reached us yet but which is beginning to be definitely felt. As this wave passes on through the four years of college, it will finally fill the institutions, but our problem is definitely to level off the crest so that we can make it fit our potential or prospective capacities. It is possible to do this by progressively taking in groups of students when and if they appear, and this can be done without curtailing programs. It should be possible to secure a much more even distribution than if we waited until a certain particular time each year to open the gates and let the already risen tide enter.

In connection with the rapidly increasing enrollment in the first years of college, it is possible to do as some colleges have done in the past; to arrange with neighboring arts and junior colleges so that part of the entering technical and scientific load may be properly borne by such colleges. The character of the work undertaken in the first two years at both the arts and the engineering college is essentially the same, and with reasonable modification it is possible to pool the educational capacities of our institutions of learning, no matter what the emphasis might be on technological work. Specifically, a survey of the conditions indicates that there is much potential capacity for scientific and mathematical training outside the professional engineering colleges.

As far as classroom instruction is concerned, there can be no particular dearth of facilities. From the material side the bottleneck will probably occur

* Percentages from figures compiled by the U. S. Office of Education.

in laboratories, in scientific or advanced technological subjects. It is interesting to note in this connection that the average college under normal conditions sometimes uses these facilities far below their maximum capacity. They are seldom used full time. The A.S.T.P. assumes that four hours per day constitutes a normal use of laboratory facilities. With an over-all 40-hour week available for the use of such facilities, the implication is clear.

The National Roster of Scientific and Specialized Personnel says: "Returns indicate that enrollments could be increased by 60 per cent if additional staff were provided."

This question of teaching personnel is a serious one, and it may be necessary to adopt the same procedures as have characterized industry in meeting the war emergency. Some teachers may have to work overtime and take something in the way of a considerable additional load until the emergency has passed. The problem is one which it seems to me is serious but in nowise insoluble. It will take on the part of the colleges imagination, original thinking, and presumes adaptability and flexibility with respect to schedules and with respect to traditional practices and procedures.

The matter is not one of extreme precision, and for that reason I have hesitated in quoting anything except overall figures and percentages. It should be borne in mind throughout the entire discussion that a sudden change in the economic situation will very definitely shift the emphasis and the pressure. This is especially true with respect to the evening work given in urban centers for a degree, and the technical work of general college grade given in special courses. During the war this type of work was developed to a very considerable extent. It is fair to assume that if jobs are plentiful and wages high, this work will assume very considerable importance.

Such facilities and such procedures as have been developed during the war and our experience there with such projects as the E.S.M.W.T. have shown that we have capacity enough to deal with any part-time load that can come to us as a post-war problem. The important thing, it seems to the writer, is to follow developments closely enough so that the entire resources of our technical colleges can be mustered at the point, at the time when the emergency exists.

Perhaps it should be stressed again that the reason this problem is so important is that not only will the veterans be benefited by adequate and proper training, but the nation as a whole will secure, as it must secure, an adequate scientific and technological personnel to ensure proper scientific development. This today is absolutely necessary for national existence. So much for the situation with respect to the possibilities of training veteran personnel in engineering and scientific fields.

This will give some idea of the order of magnitude of the problem. While the figures may in themselves be open to some question, it is believed that the estimate would be extremely helpful in an attack on the problem with the idea in mind that one significant figure is very much more significant than none at all. Since it is not possible to determine exactly when the deficit will be met, it is not critical that we know this exact date; and while the number of men involved may be expressed in round numbers, it is not fundamentally necessary to have great precision simply because in either

case it is not possible to control all of the several factors which interact. It would appear enough to know that a considerable number of engineers are immediately needed; but we would have to wait a considerable time to make up the deficit. It would be interesting and helpful to know about how long we had to wait—five years or ten years or twenty—and also it would be helpful to have some idea of the factors operating. Sometimes it is just as important to know what's going on as how much is going on, and sometimes it is very helpful to know where a road leads even if we can't tell just exactly how far it is to our proposed destination.

We have, therefore, indicated something of the character and extent of the problem and the factors working. It should be appreciated throughout the discussion that the fundamental reason such a study is necessary is not because the colleges need extra students, or perhaps not because the students in a democracy must be given training, but because, in the very nature of the present situation, this country must be assured of a scientific and technical personnel great enough to develop a proper national defense. If we are realistic, we must face the fact that this country, no matter whether alone, in combination with one or two others, or in combination with the world, must continue to develop and expand its scientific studies and its scientific research. Without even indicating that another war is possible, or that the dropping of another atomic bomb is within the limits of human imagination, it is a fact that realistically—we again repeat—this country must maintain its place in the march of scientific and technological progress. Perhaps today, instead of repeating the challenge of Cato that "Carthage must be destroyed," we might say that America must *not* be destroyed. The events towards the close of the last war brought home to every American, no matter how timid or how courageous, some of the possibilities that rest upon scientific development and research. To hide our eyes to this is the essence of foolishness. Therefore, the need for these men springs from a national need which all of us feel.

One more observation seems to be warranted and seems to be pertinent: that is that the more successful we are in the immediate post-war period in having jobs—and good jobs—for everybody, the more we will suffer in the lack of trained personnel—not only because more jobs require more men, but because more jobs requiring more men at attractive figures always cause a flow from the colleges or training centers into the industries.

So far we have dealt very largely with the technological side of the picture, and while it is perfectly true that a great many of our men of science—that is, men engaged in fundamental scientific research—enter that field through the means of technical or engineering work, it is nevertheless true that a great number, perhaps considerably more than an equal number of investigators and research men in the fields of pure science, do not come through the medium of engineering colleges, but through the science departments of universities, and colleges of arts and science. This means, of course, that the problem is one which is faced by all institutions of higher learning, and it is interesting to note that these men who do take up scientific work sometimes receive as their first degree, not the degree of Bachelor of Science, but a degree in quite a

different field. It is true that in many universities and colleges scientific aptitude is completely overlooked, and a boy never being exposed to scientific training never indicates any aptitude for it, and sometimes perhaps as much by good luck as good judgment—perhaps by the merest chance—gravitates toward or finds himself plunged into a scientific career. One of the greatest problems that faces educators today is, from the standpoint of efficiency, to gain some knowledge of the mental equipment characteristic of the scientific mind.

While the engineering colleges have made some advance, there is much to be done, particularly in the lines of pure science. In this field a man may start late—very late—and, in the nature of things, a specialized scientific education must extend very far. The time span is considerable, and the men are of the utmost immediate importance. It might be submitted further—which, after all, is the most disconcerting thing—that these men should be men of action, men of energy, as well as men of judgment and men of experience. That is, we will need always in this work of research a certain proportion of younger men with the point of view which they bring to every problem of exploration.

We have talked a great deal about the needs and our methods of filling the needs; a little perhaps about the necessity of doing this in as short a time as possible; and all these things, I think, in one form or another, are definitely appreciated by all men who know the picture. We have yet in this democracy of ours to find a way to impress upon those in authority a method of correcting what we are pleased to call a desperate situation. Legislation, executive orders and public education all have their proponents. I heard even some men indicate that something in the nature of an intellectual atomic bomb would be indicated. It seems to the writer that the situation can be met if we are careful to analyze the facts and the figures, and to realize that this business of waging war or maintaining peace or ensuring adequate national defense involves perhaps, to be perfectly realistic, professionals of two kinds: first, professional soldiers, and secondly, professional men—doctors, college men of science, engineers—who serve with these professional soldiers as professional scientists, etc., with the status in the Army of amateurs, in the sense that they are not professional soldiers. A professional soldier is—and properly is—concerned exclusively with the waging of war in its overall aspects, and he uses, by means either voluntary or conscriptive, such professional men as are available in these lines. West Point and Annapolis do not train doctors or dentists or specialized scientists—they train soldiers, professional soldiers. Such professional men are drawn into the Army as amateur soldiers, and together with other amateur soldiers, under the direction of professional soldiers, carry on a war. The question seems to be as to what place these professional civilians, as amateur soldiers, have in the picture.

It would be interesting to ask the Army to what extent professional scientists, engineers and production men have been of assistance to them as amateurs in the Army; to what extent scientific advancements and developments; to what extent fundamental design and development were worthwhile; and to what extent the production schedule of the United States with respect to the machines of war was helpful to the Army. In that way it might be

possible to appraise in words of the Army and terms of the Army something of the emphasis which we should place upon the training of these civilian professionals and amateur soldiers.

It is my considerate belief that the Army could specifically indicate to what extent, if any, such men had been valuable; and to what extent, if any, they would be valuable again—and upon this statement by the Army, base something of a training program. I for one, should be very much interested to know how it would be possible to secure, fifteen years from now, sufficient technically trained personnel when the present training program approximated roughly one-tenth the numbers trained in the post-war period.

Remembering that while we are not speaking of war or rumors of war, we are speaking of questions of fundamental scientific national defense, the Army might, and I believe can positively and will definitely, if properly approached, acknowledge a considerable responsibility toward scientific research. In case a peace is not sustained or in case a nation is destroyed, an army must be responsible. Why not ask them to bear their definite and full responsibility not only in the waging of war, but in the planning of the defense and maintenance of the future peace?

I hope I have not stressed too much the question of scientific preparation for war, or too many times the Army, but any man who sees the picture clearly must recognize that in this present situation there must be, if it is humanly possible, a high degree of coordination between an army which is striving to keep the peace and a nation which is striving to develop itself along peacetime pursuits. It is this balance of power between the civilian and the military which is important to maintain, and as in a total war the civilians are extremely important to the military, in a total peace the Army must cooperate with the civilians, and cooperation pre-supposes a compromise which involves a common objective involving different functions.

The War Project Called E.S.M.W.T. and Its Permanent Lessons for American Engineering Schools

By DUGALD C. JACKSON
of Massachusetts Institute of Technology
and FRANK D. CARVIN
of Newark College of Engineering

Part I. The E.S.M.W.T. and Its Results

In the late spring of 1944 the U. S. Commissioner of Education (Hon. John W. Studebaker) and the Director of E.S.M.W.T. (Dean George W. Case) asked us to undertake an exacting study of the processes of and the results achieved by the Engineering, Science and Management War Training (E.S.M.W.T.). As a consequence we personally made a rather detailed examination of the processes and activities of the E.S.M.W.T. central office in Washington and visited widely for observation and conference amongst the colleges and the industries participating in the work. This work by the colleges was carried out on a no-profit, no-loss basis, supported by funds appropriated by Congress and distributed through the office of the Commissioner of Education under the direction of the E.S.M.W.T. organization which the Commissioner had brought together. The original Director of E.S.M.W.T. in the Office of Education in Washington, as is well known, was Dean R. A. Seaton, of Kansas State College, and upon his return to his college the post was filled by Dean George W. Case of the University of New Hampshire.

We were given the opportunities for visiting a large proportion of the colleges and industries participating, the choice of the institutions and localities visited being left in our hands. A full report of our examination and conclusions was submitted to Commissioner Studebaker at the end of July, 1944.

The examination brought out the fact that a great influence for good in the war situation resulted from the arrangement of E.S.M.W.T., with its central office provided to make general plans and supervise execution, but the processes of execution being placed individually in the hands of approved colleges that were strong in engineering, physics, chemistry and industrial management. Mathematics was included as a feature of engineering.

The Commissioner of Education and the Director of E.S.M.W.T. have now approved the publication of a digest of our report, and, as we believe that the engineering schools of the country may profit by an understanding of what they mutually accomplished in E.S.M.W.T., and by considering what may be gained for the future by such

understanding, we have undertaken to prepare this article for THE JOURNAL OF ENGINEERING EDUCATION. The visits to colleges and industries in the far west, in the south and in the middle states were made by Professor Carvin. Those in New England and, to some degree, the middle states, and conferences regarding the central west, were mostly in the hands of Professor Jackson. The results set forth here are the outcome of our actual observations and conferences.

More than two hundred colleges participated in this project. It was started before the days of Pearl Harbor, was then called Engineering Defense Training, but after Pearl Harbor it came to be called Engineering, Science and Management War Training. It was, in each case, established by Congressional enactment and supported by annual Congressional appropriations until the war closed. The number of colleges participating in the program differed from time to time as additional colleges were approved for entering the project or now and then a college had exhausted the needs as seen by its faculty within its own area and withdrew. Our program of visiting included about fifty institutions, which we selected from among those which had been approved for courses under the program.

In addition to the colleges, some sixty industries which had participated in the program were visited. A total of some twenty thousand miles of travel were covered in the course of these field investigations. Other information was secured by personal conferences and correspondence with executive authorities of many colleges and industries which time would not permit for observation by visits.

By means of such visits it was practicable for us to assure ourselves of the degree of fidelity and wisdom with which the institutional representatives and their associates were carrying on under the plans laid down, and also to assure ourselves of the degree to which the training courses in each area had proved to be an aid to the war effort. All conclusions that we have presented are derived from information secured by us from direct contacts with authorities of the colleges carrying on E.S.M.W.T. work or with executives and employees of industries of which employees pursued E.S.M.W.T. courses. A total of more than one and one-half million trainees were taught in courses from the origination of the project to its end when the active war closed. All of the training efforts through the E.S.M.W.T. were aimed at college level. Each employed trainee had employment likely to influence many other employees affected by the trainee's association or his supervisory work. Executive officers of an impressively large proportion of the industries which had employees in the E.S.M.W.T. courses have expressed great favor for the results of the courses and have estimated the advantages derived to cover a wide variety of effects.

The objective originally stated by Congress was "to meet the shortage of engineers with specialized training in fields essential to the national defense." This was for the fiscal year 1940–41. It was soon found that the war effort in many industries would be helped by adding training programs of college level in chemistry, physics and production supervision. The Congressional Act, therefore, was expanded to provide for training designed "to meet the shortage of engineers, chemists, physicists and production supervisors

in fields essential to the national defense."

This gradual change of scope, recognized by the Congressional enactments, shows clearly the manner in which the objectives expanded while experience was being secured by the industries in regard to the aid through the colleges which was available for the industrial production needed for the purposes of war.

The higher staff of the E.S.M.W.T. Division in the Office of Education at Washington was largely composed of men of importance who came to this work on leaves of absence from important posts in colleges or industries. The organization was therefore thoroughly acquainted with industrial processes. The colleges loyally responded to the invitation to participate in the project, and nearly all those participating carried out training courses of great advantage to the war effort. Relations having been set up between the Washington office and the colleges, it became necessary to set up relations between the colleges and the industries whose employees would gain advantage from E.S.M.W.T. courses, all of which courses were provided by the Congressional Acts to be of college level. Strictly vocational courses were provided for through a different set-up, which was also supported by Congressional appropriations and centered in the Office of Education in Washington.

The relations of the E.S.M.W.T. colleges with the industries were brought about by the appointment of an Institutional Representative by each college, who made contact with the industries of the neighborhood so as to confer with the appropriate industrial administrative officers and learn what shortcomings the particular industries were feeling in regard to securing adequately trained employees for the enlarging scope of production related to the war. The instruction courses thereupon provided were of a wide range and scope in order that they might meet the industrial needs.

The wide expanse of the country and the different conditions met in various geographical areas resulted in a different amount of expenditure per trainee in like courses given in several locations. Such variations of expenditure must exist in any event on account of the varying characteristics of the many courses; but little in the way of these differences can be ascribed to lack of effort at economy by the various colleges.

Different provisions had to be made, also, as between geographical areas in which the industrial activities were densely located and other areas of important industrial production but in which the industries were quite scattered. In some cases traveling laboratories were equipped and used to serve courses remote from a college campus. Much of the teaching was done on the college campuses, much was done on the grounds of the industries participating, and some was done in borrowed high school premises or rented premises in important industrial localities. The courses were usually of short time, intensive training, given at the end of work shifts over a period of ten to fifteen weeks; but others were full-time courses operating six days a week.

As the total expenditure through the E.S.M.W.T. organization ran into large sums of money (between fifty and sixty million dollars for the total period), it is desirable at this point to refer to the financial management for carrying on under the Congressional appropriations, which became a responsibility of the Office of the U. S.

Commissioner of Education. The detailed expenditures were made by each college, based on estimates submitted for each course proposed by the colleges and approved by the Director of E.S.M.W.T. The actual expenditures made were reported to the Office of Education, along with the certification of a public accountant, but the E.S.M.W.T. Division of the Office went further in examining the accounts to assure that only authorized expenditures were made. Our exacting examination into the results convinces us that the money value returned to the nation through the improvement of production and its speeding up was several times as much as the actual money expended. In addition, the nation may properly additionally credit to E.S.M.W.T. that the improvements and the speeding up resulted in conditions which happily saved lives in the combat zones of the war.

The urgent need for the E.S.M.W.T. project was caused by the industrial picture at the outbreak of the war. There was rapid expansion of industries into the manufacture of products completely foreign to their basic products. There was development of new industries, or growth of smaller ones into large industries, both of these developments being notable. Where industrial development was most rapid, the industries made extensive and immediate use of the E.S.M.W.T. program, and in many instances the industrial authorities held that they could not have met the needs as adequately as was accomplished without the aid of this program.

Immediate use of the program occurred at those colleges already having contacts with industry through University Extension departments or like relations. Other colleges developed the program more slowly. Extensive surveys preliminary to giving courses, such as were available from Extension Departments, were of great benefit. Other institutions made special industrial surveys of their areas. The lack of industrial surveys by some institutions prevented them from making full use of the program. In some such instances stimulus to improving the programs came about through inquiries from the industries of the areas.

The growth of the new industries or the very rapid expansion of existing industries led to a great flux of employees into different centers. Many of such employees were "drifters" and not of a nature to make permanent employees; others were not adapted to the kind of employment which they sought. In any event, the turnover in some industries was extravagantly great in the early days of the war. The personnel departments of such industries were submerged by the needs of securing new employees, and for shifting ill-fitted employees in the hope that they might be brought to productive status. Such a problem is always before the American industries but only in a moderate degree under ordinary conditions. It grew to an extravagant degree during the days of the war, and industries so affected did not have opportunity to build up adequate training procedures for themselves. This was notably true where the training should be on the college level and was strongly needed for upgrading employees so as to maintain a solidarity of employed forces. The solution of these and other problems relating to the stability of employment of employees is also greatly affected by the skill of supervisors and foremen who have supervisory relations.

The E.S.M.W.T. courses in super-

visory practices proved very helpful in improving the internal relations in the industries through giving keener views of the responsibilities of the foremen and other supervisory forces. The production supervision courses for executives such as department heads also led to expressions of satisfaction and even gratitude from the industries on account of the betterment of processes and greater appreciation of the mutual understanding that should exist among departments. The result of all this has been improving stability of employment, saving of material, and saving of manpower on account of wiser executive guidance in the production problems and also in other problems which had direct influence upon production activities. Courses in improved processes of design, improved processes of inspection such as the course in quality control, improved understanding of the metallurgical processes in foundry work, and many other such subjects, also have saved waste of material, accelerated the rate of production, and saved manpower in these war industries.

Space does not permit us to go into a more extensive analysis of the E.S.M.W.T., but we cannot omit emphasizing here the advantages which were derived, under the particular conditions, from the arrangement with central supervision from the Office of the Commissioner of Education, associated with decentralized execution of the work of the project through appropriate colleges throughout the nation. In the course of our examination of the E.S.M.W.T. processes, we again and again reflected on the question of whether the industries might not have carried out this training for themselves and of themselves with equal promptness and adequacy; but the results of our observations, associated with our own thorough-going acquaintance with engineering and with industrial management, led us to a conclusive answer of *No.* In normal times large industries may be able to take care of their own needs in the way of training, from the lowest vocational needs for employees to the highest additional and refresher training for the most skilled engineers and executives. Indeed, a few of the American industries do practice such processes in peace times. These processes have satisfactorily met the needs for large industries in peace times. It is not very effective for small industries even in peace times, however, except through the cooperation of nearby colleges.

The war emergency made the need so great in numerous aspects that, not only were the existing training processes in industry swamped, but they were often inadequate in scope to meet all the needs of the peculiar conditions of the war emergency. The executives ordinarily in charge of such work were so deeply loaded with special executive and supervisory duties that it was impracticable for them to plan for prompt meeting of all the needs. It also was impracticable for them to secure suitable instructors for training courses during war conditions. Some of the long established and large industries were able to eke out most of their needs by their own well established processes but gained advantage from E.S.M.W.T. by certain special types of courses. Other industries which may have been well established but which expanded at an amazing rate on account of war conditions (like the aircraft and shipbuilding industries) had little experience in training processes for up-grading present employees or for developing the effective-

ness of potential employees. The E.S.M.W.T. was not only helpful, but it may be said to have afforded a notable contribution to the extraordinary success in the tremendous production of these industries.

A large proportion of the smaller industries of the country, which became either prime contractors or subcontractors in war service, found themselves in more or less difficulty either in regard to the quality of their products or in regard to their obtaining additional employees for their supervisory or designing purposes as the magnitude of their production grew with great rapidity. Such industries were extensive users of E.S.M.W.T. Courses often were arranged for employees of groups of small industries lying within a moderate area. Sometimes employees drove as much as thirty or forty miles two or three times a week to attend evening sessions of E.S.M.W.T. courses, the local rationing boards providing such employees with sufficient gasoline for the purpose when they clubbed together in the use of automobiles. The courses which were valuable to these industries mostly related to engineering drawing, problems of personnel management, metallurgy, production control and engineering design. An illustration of the service may be recognized in the metallurgical guidance secured by foundries which doubled or trebled their output on account of the war demands and had difficulty with the quality of their castings due to untrained hands who had to be brought in when greatly increased amounts of metal had to be melted and poured. This difficulty seems to have been overcome where the E.S.M.W.T. courses were applied to the metallurgy of foundry practice, and foundrymen, pattern makers and designers were brought into the courses for mutual understanding and joint instruction.

Under the E.S.M.W.T. regime, the instructors were provided by the college organizations, and this fact made it practicable not only to have instructors from the different colleges duly assigned to work for which they were particularly appropriate, but it also proved practicable for the colleges to borrow from various industries appropriate instructors suitable for instruction in other industries. That is, on account of the relations of the colleges which came to pass with the various industries, the loaning industry in such cases was content to make this contribution to the needs of the war emergency. There can be no doubt that this E.S.M.W.T. project made it possible for smaller industries to contribute production to the war effort to an extent and with a serviceability which otherwise would not have been within their possibilities.

Mutual grouping of smaller industries within a moderate area, for jointly utilizing the services of E.S.M.W.T. courses for training employees for upgrading, was an important effect. Competing industries sank their commercial differences for the sake of producing mutual service of aid to the war effort. Chambers of Commerce in smaller cities, and joint committees formed by the various industries in similar smaller cities, were serviceable in promoting this mutual relationship and enabling the E.S.M.W.T. to give this service. These smaller industries usually did not individually have sufficient employees who would gain an advantage by a particular course to justify the course being set up for the particular industry. With the mutual arrangement, a number of appropriate

men from a number of the industries came into the course, and the course thereupon operated for the benefit of them all. It will be observed that the elasticity in the organization of E.S.M.W.T. enabled the project to successfully give service over the wide range of needs of both large and small industries.

In addition to the large range of types of industries to which the E.S.M.W.T. gave serviceable training for employees, it also was called upon to give corresponding training to the employees of navy yards, army air service, signal corps, ordnance departments, and to employees of active bases of various other aspects of the military forces, as well as to various groups of officers.

Besides the cooperation between the colleges and the industries in this E.S.M.W.T. project, the War Manpower Commission came in actively for cooperation. It approved the types of courses which might be given, which types came in number to thirty-seven in the end. Each of these types required many intensive topics to be dealt with in the specific E.S.M.W.T. courses so that the program rose to some thousands of separate treatments. Many of these specific courses were repeated one or more times in the areas in which they were first introduced, and the large proportion of them were duplicated in different areas of the country because of the corresponding needs for the industries in those different areas.

Here and there a college apparently tended to overstep the reasonable line of demarcation between instruction of college level and instruction of the vocational-school level. This tendency was generally checked for any such institution by criticism from the Washington office of the content of a proposed course or a lack of mastery of his subject by a proposed instructor, and the college level requirement (as intended by the Congressional Acts) was generally well sustained even for the more elementary aspects of the E.S.M.W.T. work. For the more advanced aspects of the E.S.M.W.T. work, no such tendency to fall below college level was observed by us. Indeed, much of the advanced work was of a notably high order.

Part II. Responsibilities of American Engineering Schools for Continuing Active Cooperation with Industry

The success of the E.S.M.W.T. project in training industrial employees for manufacturing production in the war effort, even as carried out under great pressure for time, was so ample that it makes a strong support for the continuance, for the benefit of the nation, of active cooperation on the part of the engineering schools with the industries for additional curricular training of industrial employees; and also for the propriety of the industries providing the funds for carrying on such additional curricular instruction through University Extension departments or otherwise, while maintaining the complete independence of the colleges from industrial control.

The more elementary of the E.S.M.W.T. courses, which were mostly preemployment courses pursued by high school graduates who were competent to take up studies on a college level and also seemed appropriate to employment in war industries, were ordinarily of the nature of engineering drawing, descriptive geometry, mathematics, chemistry, physics, elementary electricity, and the like. Usually more advanced

courses were provided in the E.S.M.W.T. project to follow these elementary courses. The advanced courses particularly served for training existing industrial employees with the object of up-grading them so that they could fill vacant places carrying higher responsibilities in the growing war industries. In such cases the positions of promoted employees were likely to be filled by individuals who had taken the preemployment courses just referred to, and during the latter part of the war the demand for trainees who had completed the preemployment courses became very great.

The training processes afforded by E.S.M.W.T., usually being directed to a specific end in the way of training, have been more narrow than are usually found in college instruction, and, besides this, each of these courses would commonly compose the equivalent of only a fraction of a normal college course in any subject. For these reasons, it was made a policy that credit toward college degrees should not follow for these trainees, but that each trainee on completing a course should receive a certificate stating the subject of his course and the college which cooperated with the U. S. Office of Education in conferring the certificate. In many instances industries joined with the colleges in making something of a ceremony on conferring such certificates on a class that was just completing its course, thus emphasizing to the employees the importance of their studies. Here is a field of important scope for our engineering schools to cultivate through special organizations or through their University Extension departments. Indeed, certain of the great engineering schools have already expressed the intent to carry on this sort of work in cooperation with industries of their general neighborhoods.

The United States is jointly a great agricultural nation and a great industrial nation. In pre-war days the value of agricultural production (using the word agriculture in its broadest sense) and the industrial production were reasonably well balanced. In addition thereto must be included a full measure of the service of the great engineering units in transportation, power generation and transmission, and other collateral units which (like the manufacturing and extractive industries) come within the purview of the engineering schools.

After their experience with E.S.M.W.T. during their war efforts some industrial executives (although originally skeptical) came to feel that their companies ought to establish training organizations for their employees above the purely vocational level. Where employees of these companies have taken advantage of the E.S.M.W.T. courses there seems to have arisen a conviction alike in the minds of employees and executives of many companies that such training above the vocational level is fruitful; that is, the companies have become, as it is sometimes expressed, "training minded." Here is another important responsibility for the engineering schools and also for other colleges that are strong in physics, chemistry and management. Aid to the industries in establishing such internal instruction organizations and maintaining them suitably is a responsibility that the colleges may well assume for the welfare of the nation. This is likely to bring to our industries, and particularly to our smaller industries, a character of fruitful aid that characterizes the aid in agriculture that agricultural col-

leges of the country lend so widely to the farming population.

The work on the part of the colleges may well be of both "on campus" type and "off campus" type, the latter being carried on through University Extension or similar organizations, but limited to college grade types of instruction. Where chemistry, physics and management come in through a college which is not intimately associated with an engineering school, the institutions which are neighbors to engineering schools may well work mutually with the latter through some special organization. There is no ground for jealousy as between the engineering schools and the other colleges of the country which are strong in science and in business affairs.

The basic types of subjects in engineering *per se,* approved by the War Manpower Commission for E.S.M.W.T. in the war effort, were fourteen in number—namely, basic sciences for engineers, general engineering fundamentals, aeronautical engineering, architectural engineering, ceramic engineering, chemical engineering, civil engineering, electrical engineering, industrial engineering, marine engineering and naval architecture, mechanical engineering, metallurgical engineering, mining engineering, engineering applied to the production of textiles, foods and other war materials. Within the total of the basic types of courses approved by the War Manpower Commission were also seven designed to meet the shortages of chemists, eight designed to meet the shortages of physicists, eight designed to meet the shortages of production supervisors. Many of these come within the actual scope of existing engineering schools, but others are more pertinent to the scope characterizing other colleges. The detailed E.S.M.W.T. courses provided by the colleges ran from elementary treatments, such as might be appropriate to the freshman year of an engineering school or other college, through the gamut of needs to very high types of post graduate instruction, such, for instance, as radar and other applications of electronics, or industrial management for executives. The introduction and execution of this E.S.M.W.T. project has opened a large field of additional and collateral service by the colleges to the nation through appropriate additional technical education for the employees of industry. An exceedingly important contribution to war production was found in the nationwide use of the course in quality control by statistical methods, mostly taught through the E.S.M.W.T. organization but with the hearty cooperation of the Research and Development Office of the War Production Board. There is still much to be done in this as well as in improved safety processes, and in many other topics that ought to become integral processes of all of our industries.

We cannot take the space here to point out the types of organizations which may be used, but our comment will be limited to a few instances. One state institution, operating through its Extension Department, made use of some sixty centers for E.S.M.W.T. established in various parts of the state. These were University Extension centers applied to the E.S.M.W.T. activities in a great industrial state. Another institution, operating through a faculty committee, made an intensive survey of its state to determine the needs of various regions therein and the proper locations of training centers. It found it serviceable to establish certain centers staffed by full-time em-

ployees, while other locations in the same state could be served by part-time employees. Specialists drawn from the college faculties were thus on call to visit any center to advise on matters of course content and course operation. This system covered a region of great magnitude in a rapidly growing industrial area. In another state many new large industrial establishments grew up quite distantly located with respect to each other, and it was here necessary to organize training centers at each industry. In some cases, space was provided by the industry, but more often the local high school or civic association provided classroom space. Then the sponsoring college organized an appropriate teaching staff among the college graduates employed by that industry and appointed one of them as the supervisor for that region. Some of the difficulties observed under these various conditions were the lack of laboratory and lecture room demonstration equipment and the difficulty of close supervision of the work by the university faculties.

In some sections of the country problems developed due to several universities operating within the same limited geographical area. In such cases direct competition between these institutions may arise in their endeavor to serve the industries in that area, but difficulties that arise from competition that becomes disadvantageous may be easily overcome by mutual planning arrangements, as, for instance, by the appointment of a coordinator chosen by the interested institutions.

Part III. Final

To make the most of these potentially important, fruitful situations referred to in Part II, a thorough attitude of cooperation between the engineering schools (and also other colleges) amongst themselves is of the greatest desirability; and every effort should be made by the colleges to secure the cooperation of the industries within their areas of influence. A brief resumé article of this kind cannot go into details, but we urge that the consideration and establishment of such cooperation for the purpose concerned is of great importance to the nation's welfare. This nation is deeply dependent for the national welfare upon both the agriculture and the industries, and the engineering schools have an important responsibility for using every appropriate effort for bettering the status of the industries. The S.P.E.E., through an appropriate committee or division, could become a large influence for good by outlining the measures for meeting these important needs. It is possible that the post-war development of technical institutes and junior colleges which touch the engineering field ought to be brought within the scope considered by such a committee or division. It is our opinion that if money is made appropriately available by the states, the industries and private donors, this project may become a great educational project for the welfare of the nation, while adding definite strength to the engineering schools for carrying on within their normal fields.

Comment by Commissioner Studebaker

The foregoing article by Professors Dugald C. Jackson and Frank D. Carvin dealing with the E.S.M.W.T. program prompts me to make a brief comment. The E.S.M.W.T. plan of operation put to the test a basic concept of Federal-State relations in the field of education. That plan placed major responsibility on the participat-

ing colleges and universities, and reduced Federal direction and supervision to a minimum consistent with assuring conformity with law and effectiveness of results.

As the program approached its end, I was anxious to have made a wholly objective but yet exacting examination of the program in order to reveal whether or not the plan of operation was sound. I was delighted when the two distinguished educators accepted our invitation to make such an examination. Their standing in the profession was a guarantee of objectivity. They were asked to be critical. I did not wish weaknesses in the program to be glossed over. When their report was submitted, I felt reassured. It was obviously a comprehensive study, made with characteristic engineering thoroughness, and showed that the participating institutions have carried on their courses with honesty of purpose, commendable flexibility, and great helpfulness to industry. I am glad of this opportunity to express my deep appreciation of the excellent report made by Professors Jackson and Carvin.

J. W. STUDEBAKER,
Commissioner.

Report on Humanistic Social Studies in Engineering Education

INTRODUCTION by H. P. HAMMOND

Chairman, Division of Humanistic-Social Studies

The report which follows is one of a series of articles dealing with humanistic-social studies in engineering education that are appearing in the JOURNAL OF ENGINEERING EDUCATION during the present year. Other papers comprising the series and their months of publication are:

October, 1945, "Can Humanistic-Social Study Be Made Engineering Education" by Elliott Dunlap Smith.

November, 1945, "English and the Humanistic-Social Division" by Karl O. Thompson.

December, 1945, "The Functions of History in the Engineering Curriculum" by Stuart W. Chapman.

These articles were originally scheduled for presentation at a general session to be sponsored by the Division on Humanistic-Social Studies at the annual convention of 1945.

As stated by the authors' introduction, the Boarts-Hodges report is based upon visits to eight institutions which either exemplify various types of organization of humanistic-social studies or possess distinctive characteristics. The result is a composite view of methods and subject matter of varied types and objectives. The authors' report is condensed from a large volume of collected materials and notes on interviews with teachers and administrative officers. It is unfortunate that a great deal more of these collected materials cannot be published. The present author has found study of them not only interesting but of particular service in a study of humanistic-social studies currently in progress in his own institution.

The present report and the papers that have preceded it are sponsored by the Society's recently organized Division on Humanistic-Social Studies. The organization of this Division was recommended in the Report on Aims and Scope of Engineering Curricula in 1940 and the Report of the Committee on Engineering Education after the War in 1944. It was authorized by the Council at the annual meeting of 1944. At present the section comprises merely an Executive Committee. Since the Division is concerned neither with a particular curriculum nor a single division of subject matter, at present it has no nucleus of members. Membership is open, however, to all members of the Society who have an interest in this field. It is hoped that teachers of subjects comprising the humanistic-social curriculum stem, teachers of other divisions of the curriculum, and administrative officers will signify in-

tention of becoming members of the Section. An opportunity to do so will be extended through Society channels and it is hoped that a general session or divisional meeting such as the one projected for 1945 can be held at the annual convention of 1946.

The Division is concerned with problems of subject matter, organization of courses of study, and the integration of such courses into a stem of the curriculum. It is intended also that the Division shall sponsor the presentation and discussion of views and results of experiments in this field. In short, it is hoped that the Division can serve a purpose with relation to Humanistic-Social studies analogous to the purposes served by the divisions of the Society that deal with curricula. It is not the intent that the new division shall replace or absorb any existing division, such as the Division on English, but that it shall supplement the work of those divisions in relation, particularly, to the coordination of such materials as comprise the entire field.

The Characteristics of the Humanistic-Social Studies in Engineering Education: A Report

By ROBERT M. BOARTS* AND JOHN C. HODGES*

PART A

The Society for the Promotion of Engineering Education has, through the years, been increasingly conscious of the importance of the non-technical segment of the engineer's education. The 1940 Report on Aims and Scope of Engineering Curricula† recommended that two major divisions of the curriculum are to be recognized: the scientific-technological, and the humanistic-social. The Report of the Committee on Engineering Education after the War‡ reaffirmed the purposes of engineering education as outlined in the earlier report and set forth the objectives of the humanistic-social stem under six headings. A Division on Humanistic-Social Studies was organized in the Society to encourage and to be a focal point for activity in this field.

In January of 1945 the Executive Commitee of this Division—through its chairman, Dean H. P. Hammond—commissioned the present writers to visit eight schools and report to the Society on the charactertistics of humanistic-social studies as they are organized in these schools. The institutions, all offering a four-year course,* were selected by the Committee and were chosen primarily because of (1) the variety of plans represented in the handling of the non-technical portion of their curricula, (2) the variety of types of schools, and (3) geographical considerations in arranging the visitation tours.

The eight schools are Carnegie In-

* Respectively Head of the Department of Chemical Engineering and Head of the Department of English in the University of Tennessee.

† JOURNAL OF ENGINEERING EDUCATION, Vol. 30, no. 7, pages 555–566 (March, 1940).

‡ JOURNAL OF ENGINEERING EDUCATION, Vol. 34, no. 9, pages 589–613 (May, 1944).

* Columbia University also offers a five year course, with three years study in Columbia College and two years in the School of Engineering.

stitute of Technology, Case School of Applied Science, Columbia University, Cooper Union, Massachusetts Institute of Technology, Michigan State College, Polytechnic Institute of Brooklyn, and Purdue University. It will be noted that state and private schools are represented; that the schools vary greatly in size; and that in some schools a wide range of curricula may be found, while in others engineering and science are the chief programs offered.

In addition, the eight schools use various plans for the handling of the humanistic-social portion of the curriculum. These may be classified as

Plan 1. The articulated sequence of courses extending wholly through the four-year curriculum.

Plan 2. The lower and upper division plan, whereby the work of the first two years is distinguished rather sharply from the work of the final two years. (The arrangement of general studies in the first two years is sometimes called the pre-engineering plan.)

Plan 3. The plan of fixed required courses and rather free electives. (This plan is in wide use among engineering colleges at the present time, although many are scrutinizing their programs and restricting the freedom of election.)

But the programs of the eight schools do not, in general, fall *completely* within one of these three plans. Articulation of courses need not be prevented by a separation into lower and upper divisions; some electives are usually found desirable in every system; and the difference between *Plan 1* and *Plan 3* is tenuous, being often a matter of the allocation of responsibility for deciding the objectives of each course in its relationship to the whole curriculum. In the descriptions which follow in PART B, the schools are assigned to a classification for purposes of discussion only, and these classifications are made by the writers on the basis of present intent and present practice in the schools themselves. Because the period of visit for each school was very short—two days—there is a real danger that the visitors did not catch completely the spirit and significance of the various programs. If this is so, the fault must be attributed to a lack of acuteness on the part of the visitors, for each school gave full co-operation.

In a world regimented by the exigencies of war, a classification system has often been used to set up a priority listing. Lest anyone think that the plans are listed above in some order of efficiency or desirability, it might be wise to state here one of the fundamental conclusions reached by the authors as a result of their study:

That system is the best for any school which best meets the purposes and, objectives of the school, with due consideration of (1) the size and type of its student body and (2) the special abilities and temper of its faculty.

This is not an argument for the *status quo*. Most schools could profit from a continuous re-examination of these factors and an ordered change to a more desirable position. But the change must come from within—it is dangerous to import ready-made systems from one school to another, just as it is dangerous to impose on a country a government which ignores

the temper and culture of the people.

In this report an examination of the characteristics of the humanistic-social program of engineering education has been made under the following six major headings:

1. Organization of the Program

The form of the organization for handling the humanistic-social studies often gives the clue to the development of the program. In some cases a dean or director had charge of the activity; sometimes a committee had the main power. It is possible for the faculty itself to maintain direct supervision only when the group is small. In several of the schools the president took the leadership in guiding and stimulating the development. In general, department heads apparently did not initiate the program except with the active interest and support of the executive officer.

In schools in which engineering predominated, the initiative came usually from the highest executive officer; and the chief support came, as would be expected, from the engineering faculty. In multi-purpose universities, the initiative and control rested usually with the liberal arts faculty.

Three generalizations might be made: **The support and some initiative must come from the faculty. The process of developing this support and initiative is slow. The executive officer should, in general, not attempt to hasten the process by fiat from above, but administrative leadership is essential to any successful plan.**

2. General Objectives of the Program

The objectives of a program for the humanistic-social studies are admirably stated in the 1944 Report of the Committee on Engineering Education after the War.* Wide acceptance of these objectives was found. However, in every school in which intense activity in the humanistic-social stem was under way, it was found necessary to re-define the general objectives in light of the particular situation of the school. This work was usually done by a committee. So common was this redefinition of objectives that the authors state the following generalization without reserve:

The formulation and acceptance of general objectives must be prerequisite to the development of a strong program in any school. Failure to do so can mean only that the faculty has not come to grips with the fundamental issues which confront each school individually.

3. Curriculum

The three general plans by which the humanistic-social stem of the curriculum may be organized have been mentioned previously. The quantitative provisions and composition of the curriculum at the individual schools are given in some detail in PART B. Some general features may be noted here.

The Society for the Promotion of Engineering Education has this year issued a small pamphlet entitled "Aims and Organization." In this pamphlet the statement is made—the words are by President H. S. Rogers—that we have now completed "three definitive eras in the evolution of engineering education" and that "we are now on the threshold of a fourth era in which there is a growing professional consciousness among engineers and in

* Journal of Engineering Education, Vol. 34, no. 9, page 593 (May, 1944).

which unity of action is necessary for the public and professional welfare." Professional consciousness of public welfare is social consciousness. Such regard for social evolution is a natural result of the development of our modern civilization and its flowering in the engineer's performance of his profession. For that proper performance, the engineering instructor cannot escape his share of responsibility. This point will be revived later. The historical approach has been too often neglected in the curriculum of the engineer, where the latest equation quite often supersedes all of its predecessors. A feature of many of the programs studied in this report is the return to history as a means of laying the framework for the social studies that enter into a professional consciousness. **In programs in which social consciousness is set forth as one of the objectives of the engineer's education, the study of history as a social science has been found advisable.**

In any discussion of the place of the humanistic-social studies in the engineer's curriculum, the figure "20 per cent" is sooner or later introduced. This figure, an estimate of the minimum amount of the student's educational time to be spent on the humanistic-social stem, is found in the 1944 Report.* Probably no other feature has aroused so much attention as this one recommendation. Elaborate statistics have been developed to prove that most schools are now devoting sufficient time to the humanistic-social stem and, ergo, can rest from their labors. The figure "20 per cent" has been clothed with such sanctity that a temptation exists in some schools to bolster their score by a simple redefinition of borderline subject courses to place them on the humanistic-social stem.

On the basis of the programs studied,, the authors believe that the 20 per cent figure is only a useful guide for those embarking on a revision of their curriculum. The whole topic is resolved quite simply. **There is no magic in any predetermined allotment of time for the humanistic-social activity. The objectives set by each school and the means available will dictate inexorably what is needed to achieve the program sought; thus, a definition of a particular course as a member of a certain category is of small importance.**

4. Specific Objectives of the Curriculum Components

It is obvious that if the objectives of an overall plan are set, the objectives of the courses and groups of courses must develop and implement the plan. Co-operation in organizing and co-ordinating courses in engineering has long been the usual procedure, but a concern for the relationship between technical and non-technical courses has not been so much in evidence.

Who should formulate the objectives for the specific courses in the humanistic-social studies? A quick answer would be, the staff who gives the course; for, if they do not accept the objectives set, the rest is futile. Yet the staff of each course must receive the student from the preceding course and prepare him for the next course. Thus, the objectives of any course are partially determined by forces not directly controlled by the teaching department. Furthermore, any articulation of courses demands co-operation of means and objectives.

Of the several schools that explored

* Loc. cit., p. 594.

this matter of co-ordinating courses, the Carnegie Institute of Technology probably undertook the most extensive study. Carnegie Tech. carefully examined its courses in engineering, in the basic sciences, and in the humanistic-social stem, attempting to determine what each course needed from the one below and was prepared to pass on to the one above. A rather large committee of liberal arts, science, and engineering personnel reconciled differences in viewpoint and kept the overall objectives in focus. With that overview, the individual departments did not seem to have difficulty in arriving at mutually satisfactory objectives.

For those who might fear that such a procedure is an infringement on the academic freedom of an instructor or staff, it might be well to point out that an opposing danger looks the more formidable. In the schools visited, only one case was noted where the engineering staff had imposed its will on the humanistic-social staff. The course that resulted did not seem to be highly regarded by either group.

The greater danger—as proved by the experience of several schools—lies in the tendency of the engineering staff to allot certain hours to the non-technical work and then to ignore it, except for periodical outbursts which serve only to confuse the objectives of the courses. The liberal arts instructor should be regarded as an expert—which he is—but he should also be regarded as an active link in the chain of purposeful education.

Full and clear course objectives were found at several schools. From evidence observed, two generalizations may be formulated: **Those in charge of service and elementary courses have been dilatory in acquainting their colleagues in other divisions with the purposes, scope, and accomplishments of their several courses. The engineering staffs have been dilatory in not keeping better informed on the work of the service divisions, in not making full use of the skills already developed in the student, and in not promoting a better mutual effectiveness by conference or otherwise.**

5. Methods of Instruction

In the eight schools visited, emphasis is placed on discussion classes rather than on the lecture. This discussion method of instruction gives the student much practice in the use of inductive analysis, or the art of reasoning from specific data to the general conclusion. Such practice is particularly needed because the engineering courses are based primarily on deductive analysis. It is fortunate that the humanistic-social stem offers such a fine counterbalance of logical method.

The conference method has been used to some extent where classes could be kept small. Since the humanistic studies, in contrast with engineering, become increasingly more abstract through the four years, the conference method has been very successful in such courses as the senior seminar in philosophy at Cooper Union.

An important by-product of the shift of emphasis from lecture to discussion is the opportunity to assess the student's contribution more accurately. The result has been a gratifying increase in student effort. The engineer has seldom questioned the validity or worth of the subject matter of liberal courses, but he has often questioned the effectiveness of courses which require little work of the student. **To command the respect of engineering in-**

structors, humanistic-social courses must demand of the student a minimum level of achievement comparable to that of the technical courses.

6. Teacher Selection and Training

Increasingly, the faculties of colleges and universities are insisting that courses intended for the liberal education of the student should be designed with that object in view. Too often an elementary course taken by all students is primarily a beginning course for majors in that field. And too often these courses limit themselves to a specialized field of subject matter. As a result, survey courses have been instituted—but these have their own shortcomings. Where broad courses were found in the schools visited, it was generally insisted that these courses were not of the survey type. The aim was entirely toward the teaching of principles, with a restriction of subject matter to accomplish that purpose.

To find qualified teachers for these broad courses is difficult. The graduate schools turn themselves toward specialization. At the same time it becomes evident, from a few tentative trials, that the teaching of these broad fields is no job for amateurs. Attempts to use composite faculties, including engineers, for general courses are usually unsatisfactory.

Since intensive departmentalization tends to cut off free communication between adjacent specialized fields, some of the technical schools have begun by fusing its entire humanistic-social staff. In one school, Michigan State College, new departments for the basic courses have been established separately from the professional departments.

Whatever the means used to break the walls between departments, the staff problem is still paramount. One school, Carnegie Tech., has given financial help to selected staff members so that they can take summer school courses in fields outside of their speciality. Another school, Columbia, has a well defined plan of initiation and development for the young instructor going into its course in contemporary civilization.

Several of the administrators of these broad courses have found a solution by hiring young instructors with the master's degree and then providing them with the opportunity and incentive to continue their graduate work on a broader basis. The problem of a broad education for the instructor is now before many colleges and universities. Possibly a partial answer may be found by the establishment of divisional, rather than departmental, doctorates in the graduate schools.

The Liberal Value of Technical Courses

Probably every engineering instructor believes that his course contains elements of liberal value far beyond the purely technical aspects, and that he joins his humanistic-social colleagues in being a guardian and professor of the eternal verifies. This is undoubtedly true. Every course can be taught liberally or narrowly.

What attempt is being made to develop the general, or liberal, values of scientific and technical courses? This question, originally on the program of this study, could not be answered in the short period allotted to each school. The limited time did not permit extensive interviews *both* with non-technical and with technical staff members. But the answer to the question is fundamental to engineering education. No

one was found in the schools visited who would claim that approximately one fifth of a curriculum devoted to humanistic-social studies would, in itself, create the educated man. (It would be difficult to make that claim for any course of study.) Yet it is the hope that the student finishing the engineering curriculum will leave the school prepared to take his place in a free society and that he will be susceptible to the liberalizing effect of continuing study.

To bring this hope to fruition, the technical staff have the major responsibility. The engineering graduate is their product. They can help meet their responsibility (1) by vigorous support of the work of the humanistic-social staff, (2) by free discussion of civic and professional responsibility, and (3) by the teaching of all technical subjects in a way to bring out their inherent liberal values. The first of these is largely a matter of attitude on the part of the technical staff. The second, fortunately, is already being studied by several groups of engineers.* But the third has received too little attention. Examples of successful means for developing the broader aspects of technical courses should be made available for the guidance of the engineering teaching profession.

How Can the Aim of Liberalizing Technical Education be Best Achieved?

Of the schools studied, Carnegie Tech. and Cooper Union have endeavored, more than most schools, to organize their courses sequentially. Carnegie Tech's. courses lean toward the social studies; Cooper Union's toward the humanities. The economy of means and the careful correlation of the program at Carnegie Tech. are outstanding. At Cooper Union, the coordination of the course work with the artistic facilities of New York and the cultural aspects of the Green Engineering Camp are well worth extended study.

Two schools, Columbia and Michigan State College, have adopted the pre-engineering plan. Both are multipurpose universities, and the humanistic-social features of their curricula are available to all students. Both modify the program slightly by having one course scheduled in the junior year. At Columbia, the course in contemporary civilization has had a long and time-tested effectiveness. At Michigan State a course in biological sciences introduces a somewhat different note in engineering curricula. The pre-engineering plan has a special advantage: it makes possible the graceful discouragement of the inept engineering student before he is fully committed.

Massachusetts Institute of Technology and Purdue, large schools devoted primarily to engineering, follow a plan that requires certain courses but allows rather free electives. Both schools have excellent facilities. At M.I.T., special emphasis is given to the course on the United States in World History, which has a cosmopolitan breadth. At Purdue, the details of the program had not been fixed at the time of the visit, but English composition has been stressed.

Case and the Polytechnic Institute of Brooklyn are medium sized schools, although the evening enrollment at Brooklyn Polytechnic is extensive. Both have the required course and elective plan. Both have the advantage of the facilities of a large city,

*As, for instance, the Engineers' Civic Responsibilities Committee of the A.S.M.E.

and Case particularly has made an excellent use of the cultural institutions surrounding it. Brooklyn Polytechnic has long maintained an exacting and comprehensive program in English which is fundamental to all other courses.

It is impossible here to discuss adequately the various methods used by different schools to promote the liberalizing of technical education. As a matter of fact, however, a detailed discussion would probably fail to get at the core of the matter.

But even at the risk of being trite and oracular, this report must set down an answer to the question, "How can the liberalizing of technical education be best achieved?" Discussion with presidents, deans, directors, and instructors; observations of the working of programs in the schools visited; and finally, simply logic itself—all give this inescapable answer: **Technical education can best be liberalized by encouraging individual faculty members to achieve a broad and liberal viewpoint and to reflect that viewpoint in their teaching.**

PART B

The second part of this report attempts a brief description, often in the school's own words, of the humanistic-social stem of instruction in the curriculum of each school visited. Each description includes an enumeration of required courses, with comments on any unusual features. The position of the courses in the four-year curriculum is noted. Schools are listed alphabetically.

The Carnegie Institute of Technology

The Carnegie Tech. plan is called the *Social Relations Program.* The keynote of the plan is a careful integration of each course into the overall objectives. The *Social Relations Program* is designed to teach the student how to apply engineering orderliness and thoroughness to the problem of dealing with people and with human institutions. Esthetic objectives also are stated. The courses are organized to give the student unremitting practice in handling problems for which the data cannot be resolved by formal or scientific procedures. The working out of the articulated sequence is a masterpiece of sustained effort and thought on the part of the staff and its consultant, Elliott Dunlap Smith. It is to be hoped that Carnegie Tech's. procedures will be published for the information of other schools.

The courses required in the first year are *English Composition* (2 hrs. each semester) and a history course called the *Origins and Development of the Technological Age* (3 hrs. each semester). The latter course is described as an historical study of the rise of Western, especially American, civilization and the part played by technology therein, so conducted as to give practice in securing, appraising, organizing, and using evidence in inductive thinking.

In the second year, a continuation of the *Origins* course (3 hrs., first semester) prepares the student for *Economic Analysis of Social Problems* (3 hrs., second semester). Another two-hour course in English Composition is also scheduled for one semester in this year.

In the third year a course in *Human Relations in Industry* (3 hrs., first semester) is (1) a study of the elementary generalizations of psychology and (2) practice in using these generalizations as a central factor in ana-

lyzing typical problems of working with others. The second semester course (3 hrs.) is devoted to *English Literature,* although an approved course in art or music may be substituted.

The fourth year is devoted to a two-semester sequence of courses designed to carry a single field of study in the humanities or the social sciences to a more advanced stage. Several fields are available for election. These courses may be operated on the conference basis. They are each the equivalent of a three-hour course.

Case School of Applied Science

Case operates with the plan of required courses and electives. The program is not uniform for all major curricula. For instance, the chemists and chemical engineers take German instead of history. In addition, a senior business option, taken by about one-fourth of the students, substitutes business administration courses for the non-technical electives.

In the first year, courses are required in *Speaking and Writing* (3 hrs., first semester) and in *Reading and Writing* (3 hrs., second semester). In the second year a course in *Types of Literature* (3 hrs., first semester) is followed by *Technical Exposition* (3 hrs., second semester). A three-hour course in political history extending throughout the second year is required of all except chemists and chemical engineers.

The third year course (3 hrs. each semester) is in economics. In the fourth year, two three-hour semester courses are required (for an exception, see above), and these courses may extend over a wider range than is normally included in the humanistic-social stem. The definition under which the elective is chosen is that it shall be "non-functional in the profession of the engineer."

Case has an excellent program for encouragement of student participation in cultural activities. These are not placed on a credit basis, but are often woven into the structure of the courses. The Case Speakers' Bureau (student), the use of the musical recordings library, and the co-operation with the civic symphony orchestra, with the art museum, and with the municipal playhouse—all these are a vital part of the program for humane education at Case.

Columbia University

Columbia University is attacking the problem of the engineer's understanding of the humanities and the social sciences through a modified pre-engineering curriculum. The first two years of engineering (and other curricula) are spent in Columbia College.

The history of the program is quite long. From a war course in 1918 grew a first course in *Contemporary Civilization* in 1920. This has had continuous growth and revision. In 1929, a second year course (chiefly economics and political science) was added. From a course in the great books started by John Erskine in Columbia College, was developed a course called *Humanities A* and *B,* which was placed in the engineering curriculum in 1937. These three courses form the backbone of liberal education in the entire University. A small tutorial course in English composition is set in the freshman year primarily to detect those who need remedial work. The Engineering School follows these four courses with a course in the fourth year in specialized economics or government to meet the needs of each engineering option.

To recapitulate and summarize: In

the first year *Contemporary Civilization*, historical in nature, is taught four hours each semester. Conferences on English composition are allowed a one-hour credit in the first semester. In the second year, *Humanities A* and *B* (great books) occupy four hours each semester. Also in the second year a half-hour credit in English is allowed each semester for work requiring the use of the library.

In the third year, the *Contemporary Civilization* course devotes four hours in the first semester primarily to economic considerations and four hours in the second semester to political institutions. For the entire fourth year, each major curriculum specifies a three hour course, generally in applied economics or government, and often taught within the engineering staff.

Integration of the humanistic-social studies with the engineering teaching is encouraged by frequent conferences between the engineering and the liberal arts staffs, and by discussions in departmental meetings.

Cooper Union

Cooper Union has planned its humanistic-social program on a completely articulated basis. No electives are offered. The program has developed to meet the objectives set up in a report prepared by the staff on the qualities and skills desired in the Cooper Union graduate. It is to be hoped that this report will be published.

A single humanities staff permits a flexibility and unity of action that is sometimes lacking at other institutions. The courses are all interrelated in content and method, and the esthetic factors are presented in many ways with the help of the fine museums available.

The student devotes attention the first year to two fields: *English Composition* (2 hrs. each semester) and an *Introduction to the History of Man* (2 hrs. each semester). In the second course the student works historically with the significant trends of thought and culture of the early period of our civilization. In the second year, the *History of Man* (3 hrs. each semester) continues the historical development down to recent times. This extended work in history attempts to give each student some background of general history and some familiarity with books and other works of art and science which have been driving forces socially or sources of intense personal satisfaction.

In the third year, the undergraduate studies the social sciences (3 hrs. each semester), with particular emphasis on the economic theories and institutions that govern mankind's behavior in this realm of human activity. The earlier work in history provides a foundation for proper evaluation of current socio-economic phenomena; and, from a study of these, the student should be better prepared not only for citizenship in the broad sense but also for analysis of the more specific engineering economics which he studies elsewhere.

In the fourth year, the student takes a course in public speaking (1 hr. each semester). He also participates in one of the colloquia in *Social Philosophy*—small discussion groups in which are read some of the thought provoking books of classic dimensions. These colloquia are held in a specially stocked discussion room in the library for one two-hour period weekly throughout the year.

In addition to these formal courses, a well designed program of humane studies has been arranged to supple-

ment the technical work of the Green Engineering Camp.

Massachusetts Institute of Technology

The Massachusetts Institute of Technology has planned its program for the humanistic-social studies around a group of required courses and a number of electives. There is some flexibility of requirement and some flexibility within one course (English) for students whose preparation warrants the change.

The work of the first year is devoted to English (3 hrs. each semester), with special emphasis on logical thinking and on written and oral expression. It is not expected that the same course will be given to all students. Those who are ready for fairly advanced work in composition have an opportunity to improve their skill, especially in dealing with scientific and technical materials.

In the second year, all students take an introductory course (3 hrs. each semester) in modern history, with special reference to the place of the United States in world affairs. Students who have had substantial training in American history are allowed to take a course in the general history of civilization. In any case the work of the second year serves as an introduction to historical method and historical thinking.

In the third year, all undergraduates devote the first semester (3 hrs.) to economic principles. The case system is used in the study of certain business problems, and practical problems are integrated with economic analysis. During the second semester the student must take a three-hour course in psychology, in labor relations, or in industrial economics.

In the fourth year, the student chooses one of four options: (*a*) *History of Science and Thought;* (*b*) *Fine Arts;* (*c*) *Introduction to Literature;* or (*d*) *International Relations.* Each course meets three hours weekly throughout the year. Some departments require proficiency in foreign languages. This requirement is handled in various ways, depending on the department.

In addition to the four-year program outlined above and to the work offered in modern languages, many optional non-credit courses in the humanities and in the social sciences are made available to groups of students who desire additional instruction of this type.

Michigan State College

Michigan State, a multi-purpose university, last year adopted for all students a two-year program called the "Basic College." Seven core courses were established, each a three-hour course extending throughout one year. The courses are *Written and Spoken English, Social Science, Biological Science, History of Civilization, Literature and Fine Arts, Physical Science,* and *Effective Living.* Five of these seven courses are required of each student during the first two years. The Engineering College requires the first five mentioned, and has scheduled the fifth course, *Literature and Fine Arts,* in the third year—a year later than provided by the regular program of the Basic College.

Other features are incorporated in the new plan. Grades are given by comprehensive examinations set by a Board of Examiners. A staff of counselors, one for each hundred students, devotes half time to this activity. Two-

year terminal curricula have been established.

In order to keep each course cohesive and unified and to prevent domination by professional departments, a separate set of departments (with laboratories) has been established for the Basic College. About half of the staff members in these special departments hold membership also in the professional departments. Promotions on the staff of the Basic College are made primarily on factors other than research.

The courses, some of which are still being developed, are being designed to search out and teach the principles which underlie each comprehensive field. They are not survey courses.

Polytechnic Institute of Brooklyn

Brooklyn Polytechnic operates under the required course and elective plan. The plan has been in operation for over twenty years and is being modified slightly this fall. The courses listed here are the humanistic-social courses in the new curriculum.

In the first year, English composition is required three hours weekly throughout the year. This course operates with a large amount of individual conferences for each student. In the second semester, *American Government and Politics* is scheduled for three hours per week.

The second-year courses are *Literature* (2 hrs. each semester) and *European History* (3 hrs. each semester). The history continues into the third year with *Modern European History* (2 hrs., first semester). A two-hour course in economics extends throughout the third year.

The fourth year requires an English course in technical writing (1 hr. each semester) to supplement and aid the thesis project. The only elective in the humanistic-social stem is a two-hour option extending over the senior year. However, a foreign language must be taken in place of the history and government courses unless two units of language are offered for entrance.

Purdue University

At present, the curriculum of each of the schools at Purdue is individual in nature. A typical listing of the humanistic-social courses required cannot be made until changes in the curricula, now under way, are effected.

English Composition (3 hrs.) is required in the first semester of the first year. In the second semester, each student must elect one of the following courses: (*a*) *Informal Essay,* (*b*) *Introduction to the Drama,* or (*c*) *Introduction to Fiction. Speech* is required in some curricula. A special feature of the English program at Purdue is the work of the *Committee on Standards in English.* This committee checks the written work of juniors and seniors and then provides all deficient students with tutorial assistance and, if necessary, with a concredit course in English composition.

Approximately twenty semester hours of non-technical courses are required in most curricula. Economics is usually specified, and psychology is often elected.

ACKNOWLEDGMENTS

This paper is what it purports to be —a report. It incorporates the ideas of many individuals, shamelessly scissored from their contexts and set down here in a mutilated form that must cause sorrow to the original owners. It is not possible to identify the ideas

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Transcript—Document OR!

By JOSEPH P. VIDOSIC

Associate Professor of Drawing and Mechanics, Georgia School of Technology

One of the principal instruments of selection to many a Service school has been the university transcript.

As Director of the Army Air Forces Engineering School I had the occasion to inspect carefully thousands of transcripts from hundreds of engineering schools throughout the country. The task of evaluating these "records" was much heavier because of the unbusinesslike form of too many transcripts. And yet this document records the important beginning years of a professional career.

Many of the grading systems, number notations and subject titles are unique in the sense that they are confusing rather than revealing. Sometimes the personal data are not clearly given. Receipt and title of the degree are not always shown. The record is never complete because it omits the student's important extracurricular experience. In some instances the institute's name is obscured or even omitted. And hand additions are seldom easy to read.

Now, why such a poor tabulation? It seems that it has never been considered important enough to warrant careful preparation. Though not as decorative or even as desirable at times as the much valued sheepskin it could be made very useful to the graduate in his post-school days. But to make it this, the unsatisfactory conditions pointed out above must be eliminated.

Let us therefore investigate some of the details that might help to improve the transcript. Its simplification and standardization might well be made a project of the S.P.E.E.

First of all, every bit of information should be printed or typed. Except for the signature, handwriting should be eliminated.

The transcript should contain the following sections.

1. Name of university, college or institute.
2. Personal data.
3. Academic record.
4. Extracurricular record.
5. Statement of completion.
6. Official signature and seal.

The exact name of the school along with its location should appear at the head of the form. Following should come the personal data consisting of the student's full name, the date and place of his birth and the high or prep school from which he gained admission.

The academic record should be informative and complete. The subject nomenclature requires both a symbol and a title. The symbol should include the department identification while the title need be descriptive of the subject matter covered. It is needless to point out that much standardization could be applied here. Another bit of important

data that ought to be tabulated is the number of hours assigned to each subject, either per week or per semester. Finally of course the grade must be given. Here again much is desirable in the way of a uniform system of grades. A universally applied proficiency notation would probably simplify the interpretation of transcripts more than any other single improvement. Where a subject is repeated both grades must be clearly indicated. Groupings according to semester and year should be maintained.

The major extracurricular activities participated in by the student should be listed following the academic tabulation. The adjective major is intended to include all activities that offer experience of value to participants. The activity, the highest position occupied and the years during which active participation was undertaken should comprise this information. Any scholarship or fellowship earned by the student should appear in this section, as well as all awards won and honorary societies elected to. Where applicable, a statement indicating the extent to which a student worked his way through could properly end this section.

The statement of completion must list the exact title of the degree awarded. The class standing along with the number of graduates would provide a valuable piece of concluding information.

The transcript should now be authenticated. A school official's signature as well as the university seal is needed to correctly accomplish this.

A short investigation will reveal that actually the new form contains little more than the average transcript of today. However what is proposed is a systematization that would make the transcript a readable and useful document. Personnel managers, professional boards, government agencies and other organizations that may be in need of an applicant's college record could then review it with ease and confidence.

Some Principles of Curriculum Making

By L. O. STEWART

Professor and Head, Dept. of Civil Engineering, Iowa State College

Over the years there has been an abundance of information and discussion about the contents of engineering curricula. Yet when one sets out to build or revise his curriculum in what he would like to think is a scientific or rational manner he finds a dearth of material that refers specifically to the principles that should be applied or to the techniques that should be used. There are useful suggestions in the reports of committees of the Society for the Promotion of Engineering Education and of the various professional societies which divide the subject matter into several areas or groups and specify the percentage of the total curriculum time that should be spent on each of these areas. That is good as far as it goes. It provides a broad pattern of distribution. But more specificity is needed when one begins the actual curriculum construction, that is, the selection of the courses and the determination of the nature and amount of their contents. It is this feeling of need that impels the writer to set down some of his thoughts on this matter. Perhaps these suggestions will be helpful to others who are now trying to make curriculums that will serve postwar needs, curriculums that will do more than Topsy did, that is, "just grow."

Before proceeding further it will be wise to fix clearly in our minds what is meant by *curriculum*. The word will be used here to mean an organized group of studies or list of courses to be pursued by students who are seeking a prescribed and defined goal, usually the bachelor of science degree in one of the departments of an engineering college. Curriculum has a broader meaning, also; in which case it may properly include all of the experiences of the student which are provided or supervised by the university for the purpose of achieving its objectives. The usage in this paper will exclude those activities that are commonly referred to as *extra-curricular*. This separation and restriction is imposed so that the discussion may be contained within limits that are quite clearly defined and generally known. However, the role of *extra-curricular* activities in the education of students is significant enough to warrant their inclusion in the *planned* program or *total curriculum* of a university. The discussion of that phase of curriculum making is outside the scope of this paper.

A second limitation to be imposed is that there will be no discussion, except incidentally, of teaching methods. Again, this omission is made so that the scope of this paper may be kept within proper bounds. It is not to say that the methods of teaching that will be used in the various courses of the curriculum are of lesser importance

than the contents and arrangement of the subject matter. Doubtless, one could debate endlessly without proving which is the more important. The method that is followed when presenting material to students certainly does help in a large way to determine what they learn. Therefore, no thoughtful curriculum maker will ignore teaching methods. In the present discussion it will be assumed that the adequacy of the teaching methods will be examined and accepted for each of the courses that will be chosen for the curriculum. How that is to be done and who will do it is another story.

The typical curriculum problem in engineering is that of re-making or revising a going curriculum rather than that of constructing a new one. Even in the case where the curriculum is new in the sense that the proposed combination or grouping of courses may be different from anything that has been used, there will be some courses and groups of courses that are common or core courses for a division, school or college and must be included in any new curriculum.

Probably, very few of these curricula were built up from a plan. They just grew, course by course. The curriculum of a department of civil engineering in one college may differ markedly from that of a corresponding department in another college. Oftentimes, one can see the effect of the specialty interests of individual staff members in the titles and contents of courses. Occasionally, there may be some trading of courses between departments, a sort of "favored nation" proposition. Sometimes, a president, or a dean, or a department head selects a course, or a group of courses, that must be placed in the curriculum. Now and then, a prominent alumnus persuades his alma mater that certain deficiencies that he has observed in its graduates may be corrected by a course which he proposes. Or, a course may grow out of the expressed wishes of a group of students. At times, courses that have become useful or popular at one school are added to the curricula of other schools somewhat as one takes up the fashion of the year.

All of the foregoing are well known ways whereby courses may be added to a curriculum. For this discussion the significant point about them is not that the method of addition, or the result achieved by the course, may be good or bad, or indifferent: the significant point is that oftentimes the changes are made without the aid and benefit of a controlling plan or list of objectives for that curriculum. The preparation of a plan is the first step in an engineering enterprise. In the discussion which follows an attempt will be made to establish an orderly and rational procedure for building an engineering curriculum.

Having at hand the specific problem, which may be that of building a new curriculum or of revising a current one in a branch of engineering, the steps that may be taken include the following: (1) select the people who are to share the responsibilities for curriculum planning and organize them into groups, (2) set up objectives and other criteria, (3) choose the courses, old or new, that will give the desired objectives, (4) devise methods and machinery for appraising the results, that is, compare outcomes with objectives.

The people who should be called upon to help construct the curriculum are in the following groups: (*a*) those who are affected by it, which means students and graduates and the public, (*b*) those who use it and who are in a

position to observe the results of its use. In the latter group are found the teachers, the administrators (presidents, deans, etc.), engineering graduates, and employers of these graduates.

The contributions of these groups will differ markedly both in amount and weight. This fact is exemplified by the pattern of organization of the committees that may be set up to carry on the work. There will be a departmental committee, a divisional (representing several departments) committee, and one for the entire university, which has the task of coordinating all action. Students may participate, at the departmental level where the spade work is done, as a separate sub-committee or as members of a combined faculty-student committee. Graduates and employers will do their part most readily in the role of advisers or consultants and will make many or all of their contributions by correspondence.

Responsibility for directing this program (that of departmental curriculum changes) will fall upon the departmental committee. But there are a large number of inter-departmental interests and wishes that must be adequately presented continuously so that the final decision of the committee will be a well balanced one. Perhaps this issue may be stated concretely and simply through a brief discussion of the question, "Who will decide upon the subject matter of specific courses?" This will be mentioned again in connection with the consideration of objectives. Without going into the matter of goals or objectives, one sees at once that several groups of teachers have responsibilities for the selection of subject matter in the various courses and that these responsibilities differ widely from course to course.

Examples of courses from a typical civil engineering curriculum will help to illustrate how the responsibility varies. First, as a course where the responsibility for the determination of subject matter would be most restricted let us take one in the design of reinforced concrete structures which is studied by civil engineering students only and is taught by members of the civil engineering department. The people who should be called upon for assistance are the members of the civil engineering staff, civil engineering students, civil engineering graduates, and employers of civil engineers. Here the final decisions will be made by the civil engineering staff, with major responsibility on those who teach that course.

Second, in the order of increasing division of responsibility, would be a course that is common to several engineering curricula, for example, statics. Here the scope of responsibility would be enlarged to include the members of the department that teaches the course, the engineering students, engineering graduates, and employers of engineers. Also at this point, the Dean of Engineering would have a direct interest in the contents of a course which is in the curricula of several of his departments.

At the far end of the scale from the standpoint of mixed interest and responsibility would be a course in the principles of economics which has been prepared for the students of all schools of the university. The groups with interest in that course include the members of the teaching department and the dean of the school in which the department resides; the faculty of the various schools whose students take this economics course; the students from the various schools ranging from

those with a major interest in the field through the groups, such as those in agriculture, engineering and home economics, who seek only a general knowledge; graduates from any school of the university, and employers of graduates.

What are some of the issues or conflicting points of interest? An important one is that of goals or objectives. The degree-granting departments will insist that they know what their respective students "need"; therefore, they should have a major voice in the selection of subject matter. The department that teaches the course will claim that it knows best what should be included in the material to be taught. The graduates and employers of graduates will request that those who complete the course shall be able to do certain things, that is, have specific skills, or know designated facts, or understand various relationships. Some students will have opinions regarding the present and future usefulness of the course. The deans and the president, having in mind overall or general objectives of the schools and the university, may wish to make some suggestions.

The subject matter that is chosen for a given course should be the result of enlightened and intelligent discussion and interpretation of all pertinent information. Considerable weight will have to be given to opinions because facts are scarce and uncertain in this area. Doubtless the lead will be taken and major decisions will be reached by the department that teaches the course. It should select the subject matter after giving proper weight to the needs and desires of each of the interested groups. This is not to say that the correct contents of every course may be worked out with the precision of a machine-made product. We are not sure about all of the objectives of an education, either general or professional. The goals may be reached by more than one route. Nor should we set as our principal ultimate goal the narrow though important one of making a living. Throughout this discussion the word objective means broad educational goals as well as that of vocational competence. We can do our best job in attaining these objectives if we make the most intelligent and most complete use of all of the interests and forces that are concerned.

The discussion to this point has brought in the word "objectives" as well as the idea a number of times. Its meaning and significance for curriculum-making warrant emphasis. This ought to be easy enough to do for engineers because they are accustomed to attack and solve all of their problems according to a pattern which includes stating the "object of the experiment," or the objective. An educational objective differs from that of an engineering experiment or problem in that it is usually less concrete. Yet it is a specific goal, useful in life, that should result from a course, curriculum or program. It is what the student should be able to do, to know, or to be as a result of a specified amount of learning. The term "is useful" is used in a broad sense to mean many more things besides earning a comfortable living. It means anything that develops skill, makes one economically productive, improves health, helps one to get along with people, gives wholesome pleasure, refines one's tastes, and increases his understanding and appreciation of his environment.

These objectives are frequently listed in broad areas or categories. Four of the latter that are useful for this analysis of life's activities are: (1) earning

a living, (2) home and family life, (3) personal life, (4) social and civic life. In a recent committee report at Iowa State College the four areas used were (1) vocational or professional competence, (2) personal development, (3) social and civic responsibility, (4) human relationships. For the engineering teacher who is preparing material for a technical course the first area, professional competence, will have his primary and almost exclusive attention. However, he will have opportunities in a technical course to develop objectives in areas other than that of vocational or professional competence, which is a reason why each teacher should know the broad educational objectives of his institution and of his department as well as the specific objectives of his course.

There are several types of objectives; they may be approached from more than one standpoint; and they may be stated in several different ways. The types of objectives could be stated under the headings of *understandings, abilities,* and *attitudes,* all of which we seek to develop. Moreover, we may approach and formulate the objectives from the standpoint of the teacher, that is, what does he seek to accomplish? or from the standpoint of the student, that is, what understandings, abilities and attitudes should he acquire? Finally, we may state the objectives in at least four different ways, depending upon the grammatical form that is used.

As an example of an objective of one type, the development of abilities, and from the student's standpoint, let us illustrate the ways that an objective may be stated. The illustration will be taken from surveying. Suppose that one of the objectives in the teaching of surveying is that the student will know how to measure horizontal angles with a transit. The ways of stating the objective could be as follows: (1) the ability to measure horizontal angles, (2) measuring horizontal angles, (3) make measurements of horizontal angles, (4) to measure horizontal angles.

The precise form that is chosen is not as important as the idea which is expressed. Some objectives will be in areas of living where abstract ideas prevail. These broad or general objectives have an important part in the complete education of our engineering students. The specificity with which they may be and will be stated will vary from the most general form when they appear at the educational level of the overall objectives of the university to the most detailed and precise form possible at the individual course level. Moreover, the amount of attention that is given to each of the areas of objectives will vary as the scene shifts from the university-wide goals, through the schools and departments to the individual courses. In the same way a given course may have objectives in any or all of the areas, but it is apt to give major attention to one or more areas and minor attention to others. An important point here is that an instructor who has all of the objective before him can see to it that his course does make its best and maximum contribution toward the complete education of the student.

The recent Report of the Committee on Engineering Education After the War has helped to re-emphasize certain areas of life activities in which prospective engineers need instruction. The committee divided its objectives into two main divisions, namely, the scientific-technological and the humanistic-social. It pointed out that "it is not sufficient, however, merely to recog-

nize the purpose of these two curricular stems; it is necessary also to establish the *means* for achieving their educational objectives. Explicit objectives must be formulated not only for the major portions of the curriculum but also for each of its subdivisions in terms of knowledge to be acquired and abilities to be achieved." [1]

The committee emphasized, in speaking of the time to be allotted to the humanistic-social stem, that "they (the objectives) cannot be achieved through a three-hour course in English in the freshman year plus a three-hour course in economics in the sophomore year; that they can be achieved only through a *designed sequence* of courses extending throughout the four undergraduate years and requiring a minimum of approximately 20 per cent of the student's educational time." The significant implications of that statement for this discussion are that there must be clearly thought through and accurately formulated objectives and that there must be a designed sequence of courses that will achieve those objectives.

Every engineer is keenly aware of the importance of devices that will measure the accuracy and precision of results on an engineering project. Without these, progress would be slow and uncertain because one would not know whether the goal had been missed, just reached, or exceeded. There is a similar problem in engineering education. We have been talking about educational objectives. We need accurate methods or machinery to appraise the results of our educative process, that is, to compare what we get with what we aimed to get. For example, in connection with the objective, measuring horizontal angles with the transit, it should be possible to determine how adequately the student has learned to measure horizontal angles. When valid and reliable measuring sticks have been selected we can move with confidence to make our teaching fully effective.

Another example will emphasize the point. In the competition of collegiate football the size of the score is one measure of the effectiveness of the coach. Although winning the game is certainly not the only objective of playing and it may not be the most useful one, yet it stands as a recognized and, to many people, the only important result of the athletic training program. There is no measuring device in the academic realm that is so decisive. Many of the educational outcomes seem too difficult and too intangible to measure. Yet the importance of the educational program both in costs and in results demands that we constantly seek methods of determining the extent to which our educational objectives are achieved. Well known yardsticks for this purpose are the student's grades in college and his achievements after graduation.

The evaluations may be made at two stages in the student's career. The first of these is during his college days when he (and, presumably, the effectiveness of the educational program) is tested through the daily assignments, by various types of oral and written quizzes, by objective examinations, by essay examinations, by themes and reports and, recently, by a broad type of examination, called comprehensive, which has found increasing use as a device for testing the student's ability to use his knowledge and skills in an integrated manner. In most educa-

[1] *Journal S. P. E. E.*, Vol. 34, No. 9, May 1944, pp. 594.

tional systems the student receives a mark upon completion of a course. This represents the instructor's estimate of the extent to which the student has fulfilled the requirements of that course, which should be equivalent to measuring the extent to which the objectives have been achieved. It does not measure the satisfactoriness or validity of those objectives.

The second stage in evaluation comes after the man has completed his college work and is at work. Now the test is an evaluation of the man's overall competence and accomplishments, instead of a measure of his proficiency in course work. This is a broader test than any that the student passed in college. Although its principal features deal with his professional competence it also involves his ability in the other areas, namely, personal development, human relationships, social and civic responsibility.

It seems clear that all of these tests should have an integrated relationship to the teaching program in which the objectives are formulated and carried out. Therefore, one of the important steps in the making of a curriculum should be the preparation of tests that will truly measure the extent to which the proposed goals are reached. This is not an easy task. In college the responsibility is in the hands of the professors. After the man has graduated his employers and associates do the measuring and the professors' influence is indirect and remote. There is work to be done at both places: first, to formulate and put into use the best objectives in all areas; and second, to develop and use tests that do measure the avowed objectives. Doubtless, the carrying out of these two steps is a task for specialists and is beyond the purview of the curriculum committee. This calls for continuous research and the cooperation of all interested persons, committees and departments.

The Nomographic Representation of Polynomials

By W. H. BURROWS

Faculty Research Associate in Chemistry, Engineering Experiment Station, Georgia School of Technology

ABSTRACT

Standard methods for the nomographic representation of polynomials in three and four variables are usually given for very limited ranges of the variables. The use of ranges frequently encountered in engineering practice makes these methods inaccurate and difficult to employ. A chart has been devised for adjusting the moduli of the scales to fit the ranges of the variables, at the same time fixing the position of points on the base scale of the nomograph. Its use is described in Part I, while the method as a whole is reduced to simple steps applicable to all polynomials of not over four variables.

In Part II, two methods for the treatment of polynomials of five variables are given. Previous methods require the reduction of the polynomial to one of four variables, which is indirect, or construction of a complicated network of curves. The methods here given are direct and follow the simple methods outlined in Part I.

I. INTRODUCTION

Methods for the construction of nomographs for the solution of polynomials in three and four variables are given by D'Ocagne,[1] Lipka[3] and others. The application of these methods to engineering formulas, however, frequently leads to difficulties because of the ranges of the variables involved. The examples given by these authors generally show a range of 0 to 10 or -10 to $+10$ for each variable, whereas, in practice, it is not uncommon to find the ranges of the various variables in a single formula separated by factors as high as 10^4 or more. This wide diversity of ranges has the effect of greatly distorting the positions and moduli of the scales and proportionately reducing the accuracy of readings.

The optimum arrangement is that which gives a nearly equal spacing to the scales of the nomographs, for the ranges required, and provides each scale with a modulus such that interpolation will be easy and accurate. A method of meeting these requirements with ease and dispatch, while at the same time establishing the abscissas of the power term scale, is presented in Part I of this paper.

Part II deals with the solution of polynomials in five unknowns. This problem has been treated for the case of the complete quartic by D'Ocagne[1] and by Lipka[3] by methods involving the reduction of the complete quartic to a polynomial in four unknowns. These are substitution methods and require (a) one or more nomographs for the reduction process, (b) a nomograph for the solution of the reduced equation and (c) application of the reduction nomograph to determine the value of the original power term. Another method is presented by Hewes and Seward,[2] which, although direct, requires the construction of a very complicated network of curves and is quite difficult to operate. All three of these methods are presented in the

original texts for a very limited range of the variables and would be further complicated, with consequent loss of accuracy, by a wide distribution of ranges. Furthermore, the less direct a method is, the less accurate and more difficult to key it becomes.

Two original methods are presented here, based upon the introduction of a sixth variable, the elimination of which leads to the solution of the equation. These methods have the following advantages over those mentioned: (a) construction for any ranges of the variables is simple, following the principles presented in Part I; (b) the nomographs are easy to operate and a simple key is sufficient for each; and (c) the methods are direct, lending accuracy to reading and interpolating the scales.

The use of determinants has been omitted from the present discussion, for, while their use is invaluable in general nomographic work, they can be left out of the discussion of a single equation type without loss of generality. Indeed, it might be pointed out here that the use of determinants is valuable only in establishing the nomographic forms for different equation types, but, once the form has been established, additional determinants for other equations of the same type would be mere duplication.

PART I: A GENERAL METHOD FOR POLYNOMIALS IN THREE AND FOUR VARIABLES

II. Theoretical

Nomograph for Quadratic Equations.—The nomograph for quadratic equations is constructed as follows: (1) Two parallel linear scales are marked off at a distance, L, from each other. (2) This distance, L, is then subdivided by vertical lines into segments of length, s (measured from the left-hand scale), such that $s=Lx/(x+1)$ for the values of x within the range. (3) Straight lines are drawn through the origin of the left-hand scale to the points on the right-hand scale representing the values of $-x$. (4) The intersections of these lines with the vertical lines for corresponding values of x form a smooth curved scale for x. (5) The left-hand scale is used for values of B and the right-hand scale, for values of A. A straight line connecting any value on the A-scale with any value on the B-scale will intersect the x-scale in a value of x which is a solution of the equation (Fig. 1):

$$x^2+Ax+B=0. \qquad (1)$$

Nomograph for Reduced Cubic Equation.—The nomograph for the equation,

$$x^3+Ax+B=0, \qquad (2)$$

is constructed in the same manner as that for the quadratic except that the ordinates of the x-scale are determined by the intersections of the vertical lines with lines drawn from the origin of the B-scale to points on the A-scale representing $-x^2$ (Fig. 1).

Nomograph for the General Polynomial Type I.—The nomograph for any polynomial of Type I,

$$f_1(x)+Af_2(x)+B=0, \qquad (3)$$

where $f_1(x)$ and $f_2(x)$ may be any powers or other functions of x, is constructed as follows: (1) The A- and B-scales are laid off as before. The distance, L, is subdivided into segments such that $s=f_2(x)L/(f_2(x)+1)$. The intersecting lines are then drawn from $B=0$ to the points $A=-f_1(x)/f_2(x)$ to form the x-scale. It is obvious that both the quadratic and the reduced

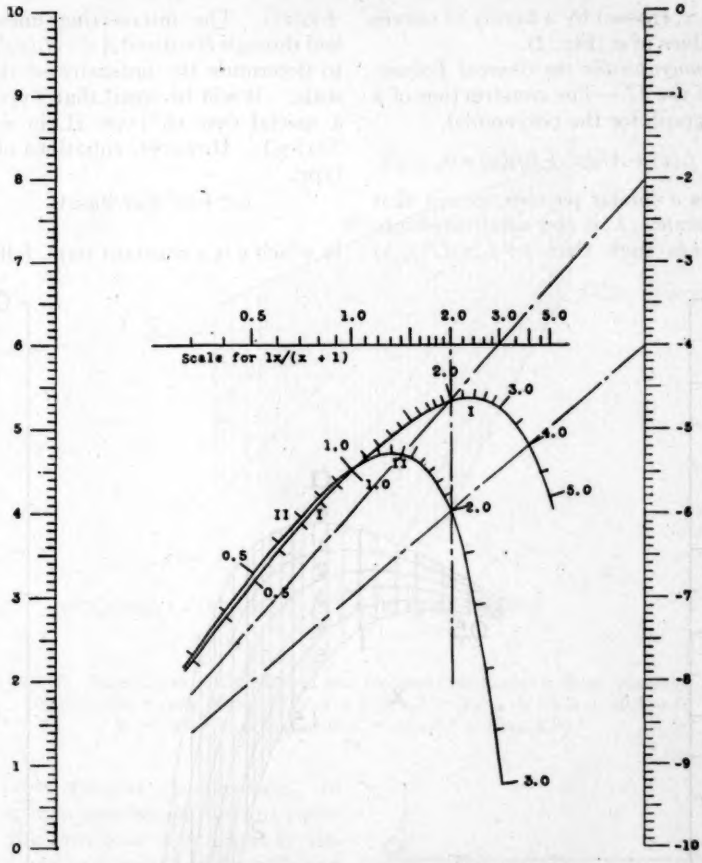

FIG. 1. Method of Constructing Nomographs for the Quadratic and Reduced Cubic Equations.

Curve I: $x^3 + Ax + B = 0$.
Curve II: $x^3 + Ax + B = 0$.

cubic mentioned above are special cases of Type I.

This general type formula may be applied, however, to more involved equations, such as the complete cubic or the reduced quartic equation (polynomials in four variables). For example, if the equation is

$$x^3+ax^2+bx+c=0, \qquad (4)$$

$f_1(x)$ may be defined by $f_1(x)=x^3+ax^2$, wherein the coefficient (a) is assigned a series of constant values, each giving rise to a separate curve for the x-scale. The resulting nomograph consists of the two parallel extreme scales with a "network" scale between. The "network" scale has vertical lines for val-

ues of x, crossed by a family of curves for values of a (Fig. 2).

Nomograph for the General Polynomial Type II.—The construction of a nomograph for the polynomial,

$$f_1(x)+Af_2(x)+Bf_3(x)=0, \quad (5)$$

follows a similar pattern, except that the distance, L, is now subdivided into segments such that $s=f_2(x)L/(f_2(x)+f_3(x))$. The intersecting lines are laid through $B=0$ and $A=-f_1(x)/f_2(x)$ to determine the ordinates of the x-scale. It will be noted that Type I is a special case of Type II, in which $f_3(x)=1$. However, equations of the type,

$$ax^3+bx^2+cx+q=0, \quad (6)$$

in which q is a constant term, fall into

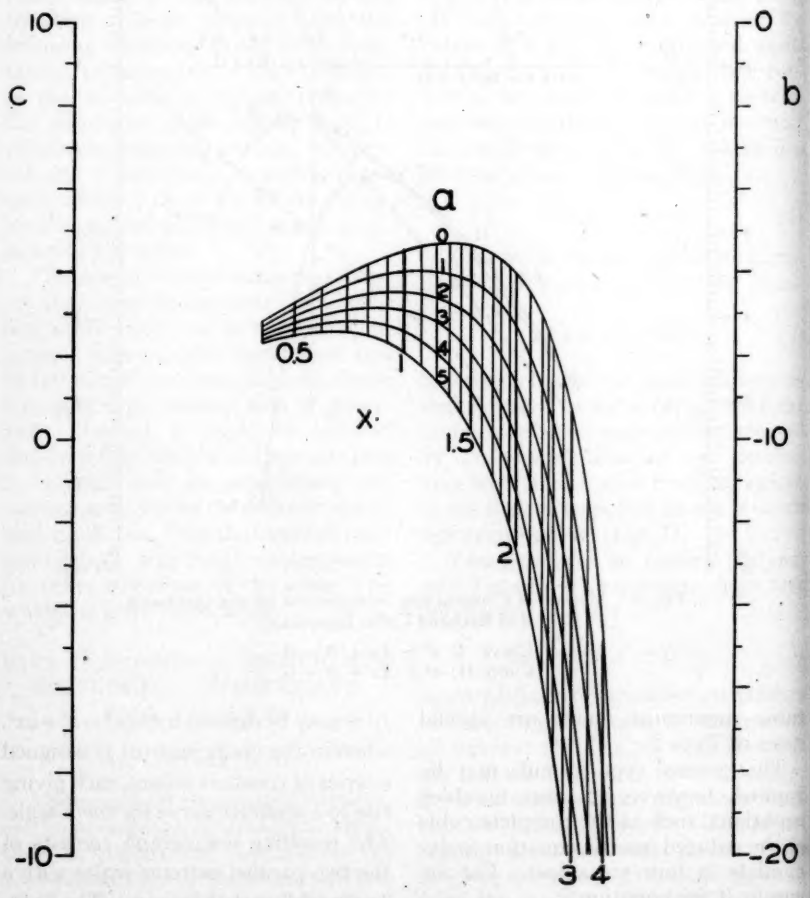

FIG. 2. Nomograph for the Complete Cubic Equation, $x^3 + ax^2 + bx + c = 0$, Illustrating the General Method for Polynomials in Four Variables.

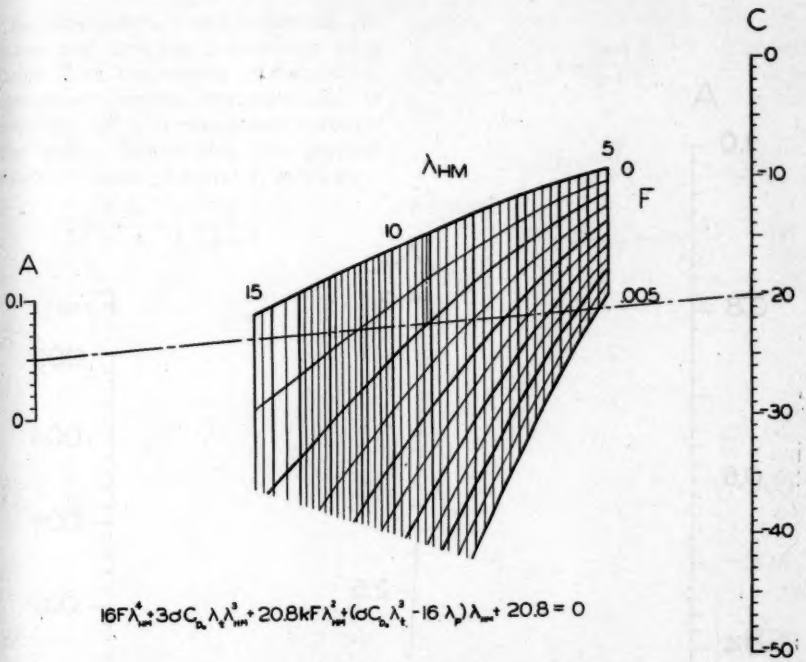

FIG. 3. Application of the Method to a General Polynomial in Four Variables. The equation is reduced to $16F(\lambda^4_{hm} + 9.1\lambda^2_{hm}) + A\lambda^3_{hm} + C\lambda_{hm} + 20.8 = 0$ in which $A = 3\sigma C_{D_0}\lambda_t$ and $C = \sigma C_{D_0}\lambda_t^3 - 16\lambda_p$, $k = 7$.

the more general classification. In setting up a nomograph for this equation, the functions of x might be defined by: $f_1(x) = ax^3 + q$, $f_2(x) = x^2$, and $f_3(x) = x$.

Typical examples of these various types are shown in Figs. 3 through 5.

Proof of the Construction of the Above Polynomial Nomographs.

Let

$$s = \frac{Lp}{p+1},$$

then

$$r = \frac{sq}{L} = \frac{pq}{p+1}.$$

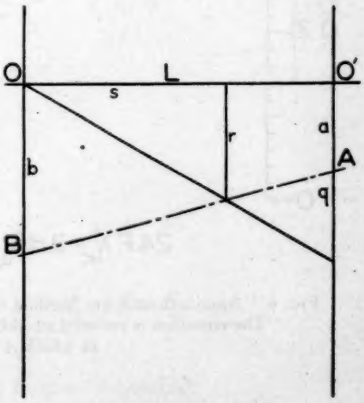

Diagram No. 1

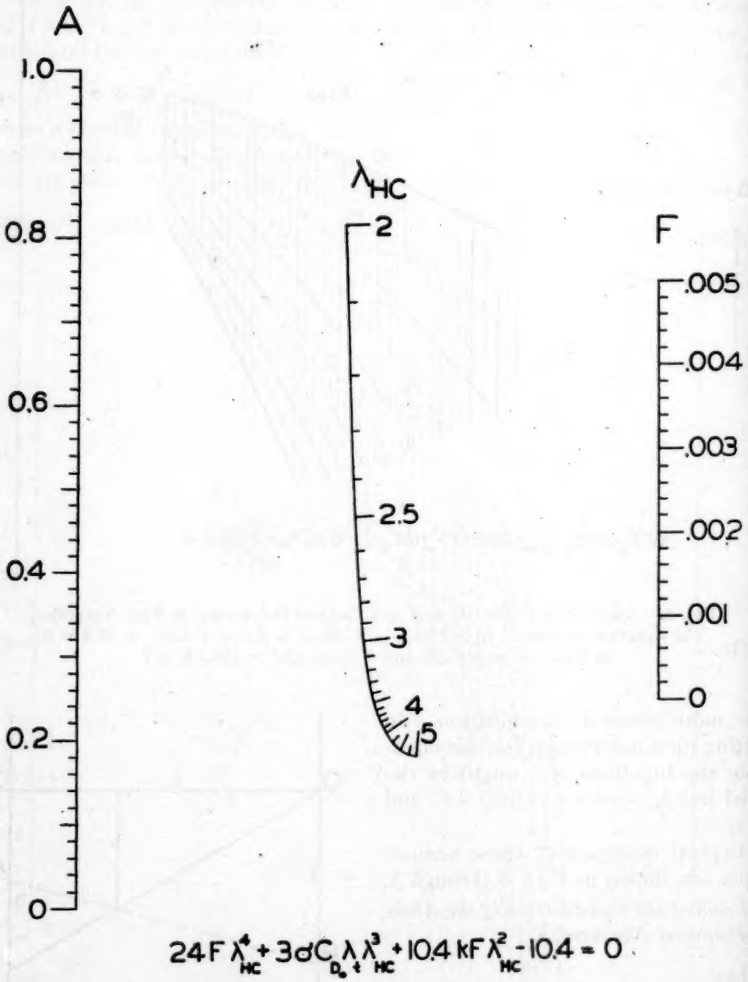

FIG. 4. Application of the Method to a General Polynomial in Three Variables. The equation is reduced to $24F(\lambda^4_{hc} + 3.03\lambda^3_{hc}) + A\lambda^3_{hc} - 10.4 = 0$, in which $A = 3\sigma C_{D_0}\lambda_t$, $k = 7$.

The parameters, s and r, are the abscissa and ordinate respectively of a point R on the x-scale as defined by the above construction methods. If any line, BRA, is now passed through this point, intersecting the parallel scales in values of a and b, we have

$$\frac{b-r}{b-a}=\frac{s}{L}=\frac{p}{p+1},$$

or

$$r=\frac{ap+b}{p+1}$$

but

$$r=\frac{pq}{p+1}$$

whence

$$-pq+ap+b=0. \qquad (7)$$

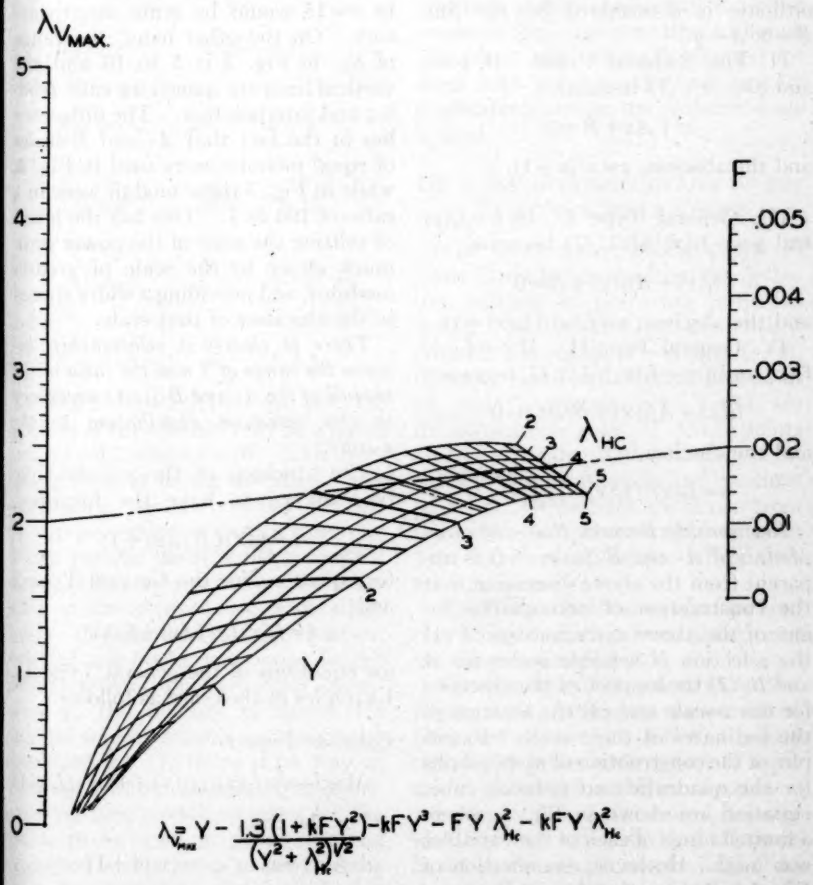

FIG. 5. Application to a More Involved Polynomial.
The equation is written: $f_1(Y, \lambda_{Hc}) + f_2(Y, \lambda_{Hc})F + f_3(Y, \lambda_{Hc})\lambda_{V_{max.}} = 0$ and a separate Y-curve is plotted for each value of λ_{Hc}.

Now, the A- and B-scales are so constructed that $A=a$ and $B=b$. (The construction of these scales will be given later.)

We then have four cases for Eq. 7:

I. The Quadratic. If $p=x$ and $q=-x$, (7) becomes

$$x^2+Ax+B=0,$$

and the abscissa, $x=x/(x+1)$. (The ordinate is determined by the line $B=0$, $A=q$.)

II. The Reduced Cubic. If $p=x$ and $q=-x^2$, (7) becomes

$$x^3+Ax+B=0,$$

and the abscissa, $s=x/(x+1)$.

III. General Type I. If $p=f_2(x)$ and $q=-f_1(x)/f_2(x)$, (7) becomes

$$f_1(x)+Af_2(x)+B=0$$

and the abscissa, $s=f_2(x)/(f_2(x)+1)$.

IV. General Type II. If $p=f_2(x)/f_3(x)$, and $q=-f_1(x)/f_2(x)$, (7) becomes:

$$f_1(x)+Af_2(x)+Bf_3(x)=0$$

and the abscissa,

$$s=f_2(x)/(f_2(x)+f_3(x)).$$

Relationship Between Range of x and Moduli of A- and B-Scales.—It is apparent from the above discussion that the construction of nomographs for any of the above cases consists of (1) the selection of suitable scales for A and B, (2) the location of the abscissas for the x-scale and (3) the location of the ordinates of the x-scale. Examples of the construction of nomographs for the quadratic and reduced cubic equation are shown in Fig. 1, where a limited range of each of the variables was used. However, examination of Fig. 2 will show that for some ranges of the variables the nomographs would have a very distorted appearance and would lack the desired accuracy. This is much more pronounced in nomographs involving a network scale, because of the crowding of the vertical lines as we approach the A-scale.

For instance, in Fig. 2, the spacing of the vertical lines for the range, $a=0$ to $a=4$, is satisfactory for easy reading. However, it is obvious that readings in the neighborhood of $a=10$ to $a=15$ would be quite unsatisfactory. On the other hand, the range of λ_{hm} in Fig. 3 is 5 to 10 and the vertical lines are spaced for easy reading and interpolation. The difference lies in the fact that A- and B-scales of equal modulus were used in Fig. 2, while in Fig. 3 these moduli were in a ratio of 100 to 1. This has the effect of shifting the scale of the power term much closer to the scale of greater modulus, and providing a wider spread in the abscissas of that scale.

There is clearly a relationship between the range of x and the ratio of the moduli of the A- and B-scales necessary to give optimum distribution to the x-scale.

The abscissas of the x-scale have been shown to have the formulas,

$$s=f_2(x)L/(f_2(x)+1)$$

for equations for the General Type I and

$$s=f_2(x)L/(f_2(x)+f_3(x))$$

for equations of the general Type II. Examples of these are as follows:

Equation Type I:

$$\text{Abscissa}=f_2(x)/(f_2(x)+1)=s(L=1)$$

For the case,

$$f_2(x)=x, \qquad s=x/(x+1)$$

For the case,

$$f_2(x)=x^2, \qquad s=x^2/(x^2+1)$$

For the case,

$$f_2(x)=x^m, \qquad s=x^m/(x^m+1)$$

Equation Type II:

$$\text{Abscissa}=f_2(x)/(f_2(x)+f_3(x)) \qquad =s(L=1)$$

For the case,

$$f_2(x)=x^n, \qquad s=x^n/(x^n+x^{n-1})$$

and

$$f_3(x)=x^{n-1}, \qquad =x/(x+1).$$

For the case,

$$f_2(x)=x^n, \qquad s=x^n/(x^n+x^{n-2})$$

and

$$f_3(x)=x^{n-2}, \qquad =x^2/(x^2+1).$$

For the case,

$$f_2(x)=x^n, \qquad s=x^n/(x^n+x^{n-m})$$

and

$$f_3(x)=x^{n-m}, \qquad =x^m/(x^m+1).$$

It will be noted that in any case, the formula of the abscissa may be written $s=p/(p+1)$, where $p=x^m$. This function gives rise to the so-called "projected scale," since it may be generated by the projection of points from one of two parallel linear scales through a diagonal line to a point on the other scale on the opposite side of the diagonal. The method is described in most of the books mentioned in the bibliography. The principal objections to the practice of using this method whenever such a scale is to be employed are (1) there is no way of knowing without considerable experience the best moduli to select for the scales to be used in generating the projected scales, so as to provide the desired distribution of points on this scale, and (2) the projection operation is often tedious and liable to error, especially where the moduli of the A- and B-scales are very different. It is highly desirable, then, to have a more convenient method of locating the abscissas of the x-scale.

We have found that the use of the chart shown in Fig. 6 is advantageous in two respects: first, it selects the optimum ratio of the moduli of the A- and B-scales and, secondly, it locates the abscissas of the x-scale without further construction. Incidentally, although this chart was originally devised for work with polynomials, it is equally applicable wherever the projected scale is used.

III. Construction and Use of the Projected Scale Chart

The construction of the projected Scale Chart is derived from the orthodox method of preparing projected scales. Two parallel lines are marked off with the scales, $O'-A$ and $O-B$, of equal modulus and with origins at O' and O, respectively. Lines are drawn from the point, O', to the points on the B-scale, with differences in shading to indicate units and fractions of units. Other lines are drawn from the point, O, to the unit points, from 1 to 10, on the A-scale. (Fractions are unnecessary.)

The B-scale is not shown in the final chart, Fig. 6, since it is not used, once the chart is completed.

The line from the point, O, to the point, $A=1$, intersects the pencil of lines first drawn in a series of points representing the scale $p/(p+1)$ as it would be formed in the usual manner, were the moduli of the A- and B-scales identical and their vertical distance equal to the length of the line, O to $A=1$. If the modulus of the A-scale were twice that of the B-scale, the distance of the point, O' from the

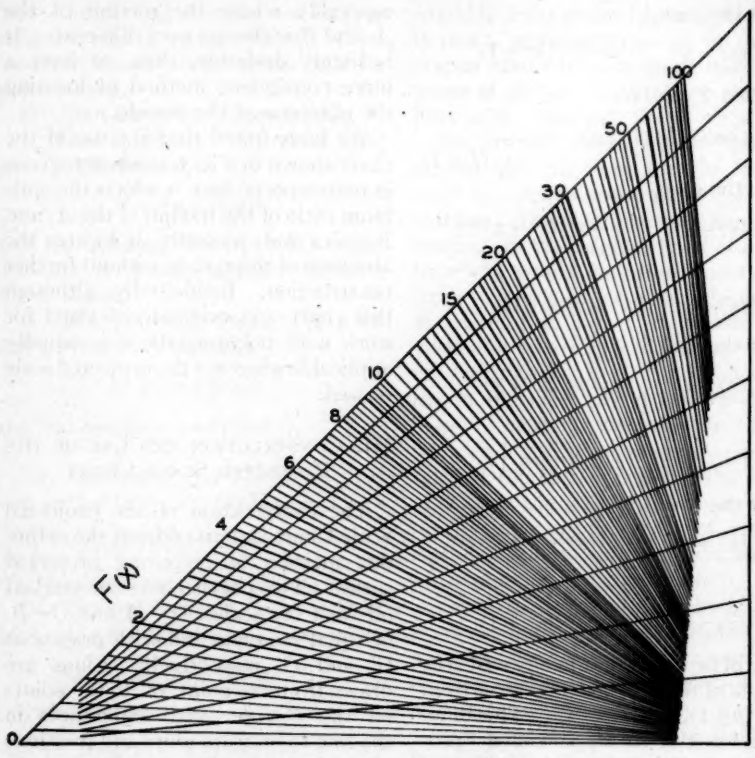

FIG. 6. The Projected Scale Chart.

diagonal (as measured along the B-scale) would be twice as great, the projection by the usual method would give rise to a scale identical with that on the line, O to $A=2$. In the same manner, each of these lines, O to $A=n$, is intersected in such a way as to give rise to a projected scale identical with that which would be formed in the usual manner, were the ratio of the modulus of the A-scale to that of the B-scale ($m_A : m_B$) equal to the number, n, on the A-scale of the chart, and were the vertical distance separating the scales equal to the distance, O to $A=n$. Each of these lines may, therefore, be used as a scale for establishing the spacing of the abscissas of the function $p/(p+1)$ between the extreme scales, provided the line used corresponds to the ratio of moduli being used on the extreme scales.

The range of values to be represented on the projected scale will determine which of the O to A lines to select, and, consequently, what ratio of the moduli to employ in setting up the A- and B-scales on the nomograph. For instance, if the range of $f^m(x)$ is 1 to 5, it will be seen that this range falls

approximately in the center of the line, O to $A=2$, and extends over a longer portion of this line than any other line. Hence, a ratio of $m_A : m_B = 2$ would be employed. Also, the line O to $A=2$ would be employed to establish the positions of the vertical lines used for the abscissas of the x-scale.

The chart, as shown, gives values of $f^m(x)$ from 0 to 100 and values of $m_A : m_B$ from 0 to 10. However, either of these scales may be multiplied by any factor, provided the other scale is multiplied by the same factor. For instance, to set up a nomograph wherein the range of $f^m(x)$ was to be 25 to 250, one would multiply both scales by 10. This would place 25 at the present position of 2.5 and 250 at the present position of 25. This range would fall approximately in the middle of the line, O to $A=10$, which line would be used in establishing the abscissas of the x-scale. Then, since the values of both scales have been multiplied by ten, a ratio of $m_A : m_B = 100$ would be employed in setting up the A- and B-scales.

IV. Outline of the Method

1. Put the given equation into the form of either General Type I:

$$f_1(x) \pm A f_2(x) \pm B = 0,$$

or General Type II:

$$f_1(x) \pm A f_2(x) + B f_3(x) = 0.$$

If the original equation contains four variables, incorporate one of them as a "variable constant" in $f_1(x)$.

2. Determine the range of $f^m(x)$. For Type I equations, $f^m(x) = f_2(x)$; for Type II, $f^m(x) = f_2(x)/f_3(x)$. Find the $O-A$ line on the Projected Scale Chart which most nearly centers on this range of $f^m(x)$. The number, n, on the A-scale of this chart gives the ratio of moduli $(m_A : m_B)$ of the A- and B-scales to be constructed on the nomograph.

3. Construct the A- and B-scales, giving attention to the following details:

(a) Both scales must read in the same direction; *i.e.*, both scales must become of higher positive or lower negative value as we move in one direction.

(b) Each scale must be long enough to include the full range of its coefficient with the desired accuracy of subdivision.

(c) The moduli of the scales must stand in the ratio $(m_A : m_B)$ determined in Step 2.

(d) If the nomograph is being constructed on tracing paper, these scales may be drawn from points on a piece of cross-section paper placed under the tracing paper at such an angle as will give the required modulus to each scale.

(e) In order that the values of x read from left to right, it is desirable to place the B-scale at the left and the A-scale at the right of the nomograph.

4. Place the selected scale of the Projected Scale Chart (Step 2) so that the point, O, is on the B-scale and the point, n, is on the A-scale. Mark on the nomograph the points of intersection which the diagonal lines make with this scale, over the range of $f^m(x)$, and draw vertical lines on the nomograph through each of these points. Label these lines with values of x (not with values of $f^m(x)$).

If the nomograph is being laid out on tracing paper, the chart may be placed in position beneath the paper and the vertical lines drawn directly from the points on the chart.

5. Set $B=0$ and solve the equation for A in terms of x. Determine the

value of A for enough separate values of x to provide a smooth curve.

If the equation contains four variables, one of the coefficients will have been incorporated in $f_1(x)$ as a "variable constant." In this case, separate sets of values of A must be determined for at least two values of the "variable constant."

6. Set a pivot pin at the scale point, $B=0$, and lay a straight-edge from this point to each value of A determined above. Mark the point of intersection of the straight-edge with the vertical line for the corresponding value of x. Draw a smooth curve through these points of intersection.

In the case of a "variable constant," a separate curve will be obtained for each value of that coefficient. Intermediate curves may be set up by linear interpolation along the vertical, if the ordinates are linear functions of the "variable constant," as they usually are.

PART II: TWO METHODS FOR POLYNOMIALS IN FIVE VARIABLES

It has been shown in Part I that a polynomial in four variables can be put into nomographic form by incorporating one of the coefficients of the power term, as a "variable constant" in $f_1(x)$ in either Type I or Type II Form. The resulting nomograph contains a "network" scale, in which the abscissas represent the power term and the ordinates, the "variable constant."

This device can be applied to polynomials in five variables by assigning two of the coefficients as "variable constants" in the expression for $f_1(x)$, only by preparing a series of nomographs, one for each integral value of one of these coefficients, with the other coefficient represented in the "network" scale of each nomograph. Such a device might conceivably be used if one of the coefficients had a very limited set of possible values, but could hardly be used as a general method.

The following methods consist in the introduction of a sixth variable, P; factoring into two expressions, each containing x and P and two coefficients; and arranging these in nomographic form such that simultaneous solution will eliminate the parameter, P, and yield the desired root of the equation. Both methods will be treated for the case of the general quartic, $x^4+ax^3+bx^2+cx+d=0$, but may be applied to other polynomials in five variables.

First Method.—The general equation for the quartic is written in parametric form as:

$$(x^4+d)+bx^2+P=0, \qquad (1)$$

and

$$-ax^3-cx+P=0, \qquad (2)$$

with the following specifications: for Part 1 of the nomograph,

$$f_1(x)=x^4+d, \quad A=b \quad \text{and} \quad B=P$$

and for Part 2,

$$f_1(x)=-ax^3, \quad A'=-c \quad \text{and} \quad B'=P.$$

It will be noted that the two parts of the nomograph have a common scale, $B=P=B'$. The moduli of the A- and A'-scales are made such that the moduli of the B- and B'-scales are identical, and the same scale is used for both B and B'. Part 1 of the nomograph is placed on one side of the P-scale and Part 2 on the other side. In practice, this P-scale is not scaled, since the only significant point on it is the zero point used in setting up the ordinates of the network scale. The two parts of the nomograph are set up as previously described for polynomials in four variables (Fig. 7).

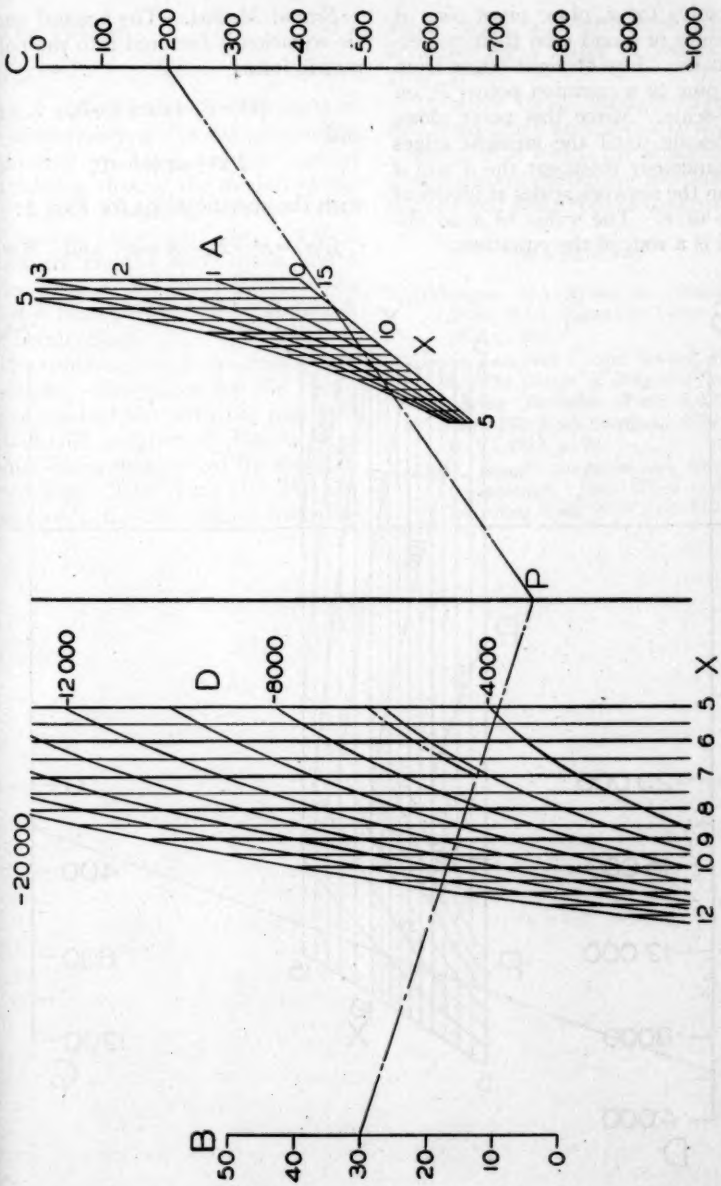

FIG. 7. First Method for Polynomials in Five Variables.

To solve for x, place pivot pins at the values of b and c on their respective scales. Lay straight edges from these pins to a common point, P, on the P-scale. Move this point along the P-scale until the straight edges simultaneously intercept the a and d lines on the network scales at identical values of x. The value of x so obtained is a root of the equation.

Second Method.—The general quartic equation is factored into the parametric form:

$$(x^2-P)+ax+b=0, \qquad (1)$$

and

$$Px^2+cx+d=0, \qquad (2)$$

with the specifications for Part 1:

$$f_1(x)=x^2-P, \quad A=a \quad \text{and} \quad B=b,$$

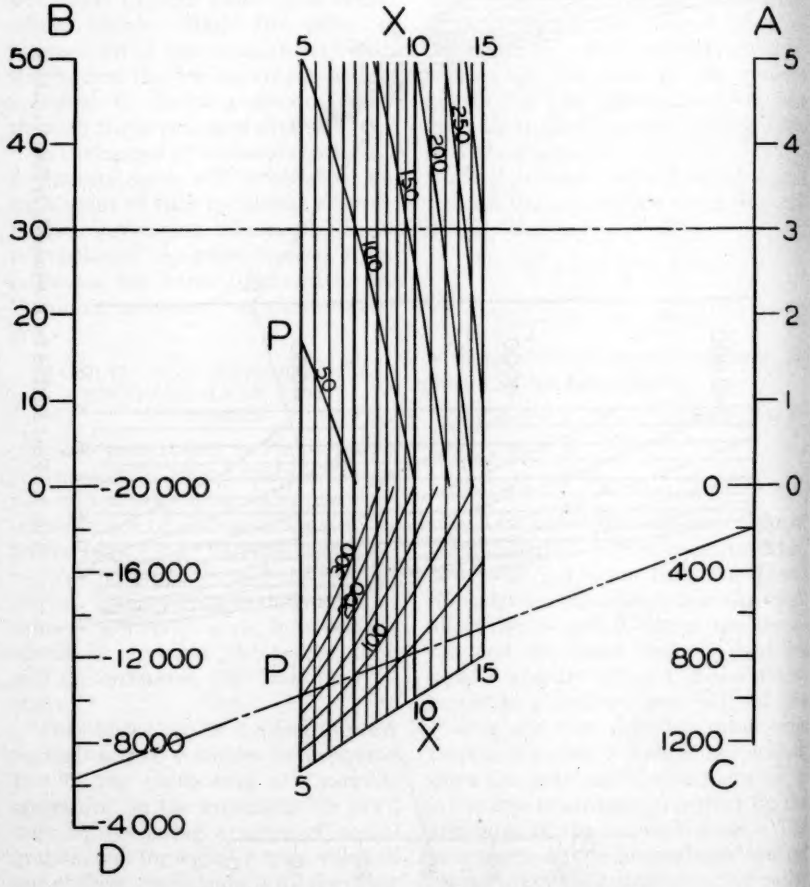

FIG. 8. Second Method for Polynomials in Five Variables.

and for Part 2:

$$f_1'(x) = Px^2, \quad A' = c \quad \text{and} \quad B' = d.$$

Since A and A' are both coefficients of the same power of x in the parametric equations, we have the very useful relationship that: if the moduli of the a, b, c, and d scales are in the ratio, $m_a : m_b = m_c : m_d$, and the c and d scales are colined with the a and b scales, respectively, then the abscissas of x for both parts of the nomograph will be identical.

The construction of the nomograph is simple. The scales for the coefficients are laid out with the positions and moduli mentioned, the ratio of moduli being determined by the Projected Scale Chart (Part I). The abscissas of x are determined from the same chart, and ordinates are constructed for a range of values of P (Fig. 8).

To solve for x, straight-edges are laid from a to b and from c to d. The value of x at which the straight lines simultaneously intercept identical values of x and P is a root of the equation.

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Further Notes on Analytic Geometry

By SAMUEL B. FOLK

Professor of Mechanics, The Ohio State University

For several long months I have been hopefully awaiting an article on Analytical Geometry in answer to Dean Ayer's iconoclastic observations on its value to engineering students (April 1944 issue of the JOURNAL). I, for one, do not feel that the discussion of this topic should die with the Dean's own answer in the October 1944 issue.

There are a number of opportunities to utilize analytic geometry in theoretical and applied mechanics. One such occurs in the derivation of column formulas. For a number of years I have encouraged my students to apply their knowledge of "analyt" for this. Each time I hear groans and an unashamed admission that what little they once knew has been forgotten. If left to their own resources they will always use the calculus for these problems, even though they realize their shortcomings in the application of this subject. To the average student, analytic geometry is a method used in solving some problems which next quarter we find can be worked by a "slick" method called calculus. To be useful to the student he must find applications for a subject during the next quarter. But there is little or no "carry-over" factor in this subject. Therefore, he forgets nearly everything except $y = mx + b$ and this is not worth remembering because it can be synthesized from algebra and calculus. Some engineers would solve these problems by descriptive geometry.

Neither do I mean to infer that all topics of analytic geometry should be dropped. Some curve plotting and equations would be perfectly at home in the calculus, and some time could be saved in our crowded engineering curricula. If any of your engineering colleagues believe, like some of Dean Ayer's and mine do, that the subject be retained, try asking them a few questions, such as:

"What is the common name for a hyperbolic paraboloid?"

"Of course you know that the parabola, ellipse and hyperbola are conic sections, and that they are defined as curves where the eccentricity is equal to, less than or greater than unity. Now just which one is which?"

"Have you ever used in your professional work the hyperboloid of revolution of two sheets?

"If you were finding a perpendicular from a point to a line, would you use analytic geometry or descriptive geometry, and why?"

"What is the latus rectum and for what is it used?"

"Just how recently, or how often, have you used Analytic Geometry?"

These questions are not meant to be embarrassing but only to really see

if the colleagues mean what they say about the value of the subject. Remember that analytic geometry was a good method of analysis when proposed by Des Cartes in 1644 and that Newton was only two years old then. But the methods became less valuable after we knew how to handle the calculus and especially after Gaspard Monge published his studies on descriptive geometry in 1795. As a matter of interest in retrospective, Wolf devotes no space at all to Des Cartes in his chapter on Mathematics in "A History of Science, Technology and Philosophy in the 18th Century."

Most of our curricula revisions in Engineering Colleges are merely rearrangement of present existing courses. Why shouldn't subject matter, continuity, logical sequence and practical value be examined? Isn't there an immense field of improvement here that is pretty much overlooked? Under pressure of time, should we not somewhere draw the line and eliminate subject matter that has little or no value in the engineering sequence? Or perhaps we should catalog such courses as broadening rather than fundamental or basic to engineering. This would at least relieve the mind and avoid putting our courses under the microscope, and we could go merrily on our way for another half century. But should we?

Further Notes on Engineering in the Middle Ages

By J. K. FINCH

Renwick Professor of Civil Engineering, Columbia University

In his interesting review in the October JOURNAL of the progress of civilization during the Middle Ages and the Renaissance, Professor Draffin outlined the effect of social and political changes on the general development of engineering.* The long period from the collapse of the Roman Empire in the West to the fruition of the new civilization in France, some thousand years later, includes, however, a number of most interesting angles which were not noted, or at least not developed, in Professor Draffin's paper. One gathers the impression, in fact, that the Middle Ages were a rather sterile and unimportant era in the history of engineering, whereas they were marked by a number of notable achievements in the history of our profession.

In the first place, the Middle Ages gave us for the first time the words *engine* and *engineer*. Neither the Greeks nor the earlier Romans ever used the word engine. Vitruvius attempts to distinguish between a *machina* or an *organon* but he never heard of or used the word *ingenium*. It was an early father of the Latin church, Tertullian, who, writing about 200 A.D., recounts how the Carthaginians, when a Roman battering-ram (*aries*) was brought up to attack their walls, were dumb-founded at the sight of this "new and foreign *ingenium*"—that is, product of genius, or invention. While it seems rather extraordinary that this device was unknown to the Carthaginians, for it had been used centuries earlier by the Assyrians, nevertheless, this was, apparently, the origin of our word engine.

Thus, thereafter, catapults, battering-rams and other similar devices of war gradually became known as engines but it was not until some thousand years later that the men who operated them were referred to as *ingeniators*, or engineers.

It was also during the Middle Ages that the split began to develop in the ranks of the old master builder which led to the wider use of this new designation. All through Ancient Times, up to this period of the ingeniator, there had been but one profession the workers in which turned their hands to what we would now call architecture, civil or mechanical engineering, or military engineering, as the times and occasion required. There was undoubtedly some specialization but the word master builder seems the most appropriate to apply to these earlier general practitioners. The Egyptians called them chief of works, the Greeks knew them as arch-technicians, *architekton*, and the Romans, following Greek practice, used the name *archi-*

* "The Status of Engineering During the Middle Ages and the Renaissance" by Jasper O. Draffin. JOURNAL OF ENGINEERING EDUCATION, Vol. 36, No. 2 (October, 1945).

tectus. This is the origin of the modern word architect but the earlier meaning was not limited, as it is today, to building construction. The ancient *architectus* was a general master-builder engineer and architect.

During the Feudal Ages, however, the men who specialized in making and operating engines of war and who could build private fortress-homes for the many nobles who, operating on a public-be-damned policy and giving only lip allegiance to the crown, made this the Era of Private Wars, were in great demand. They became the *ingeniators*, the first to be known by the name "engineers." I suggest that those who think that their work was relatively stumbling and child-like study their engines and, in particular, the medieval fortress. Evolving from the Roman *castrum*, or armed camp, earlier timber walls and towers gave way, about 1100 A.D., first to square and later to round tower constructions which, together with the Gothic cathedrals, still are one of man's greatest structural achievements.

For example: About sixty miles north of Paris, just south of Soissons, there stand the remains of one of the most famous of these structures. The Sieur de Coucy erected this famous Chateau of Coucy early in the 13th Century. The great king of the Cathedral Age, Philip Augustus, had died in 1223 and the Chatelain of Coucy decided it was a good time to rush up an impregnable fortress-home before the new king could get his forces together and stop him.

Standing on a commanding spur of the hills of a tributary of the Marne, Coucy was protected on three sides by steep slopes. A great ditch, seventy feet wide, was cut across the spur, thus guarding its only approach. Flanking towers cornered the walls, a drawbridge and complicated portcullis and entrance gate guarded access to the central courtyard, while the huge donjon, or keep, the final retreat of the defenders and thus the ultimate center of resistance, was, according to Violett-le-Duc, "the most superb military construction of the Middle Ages." This fortress-home was opened by no single lock. The attacking force faced a series of carefully, ingeniously planned obstacles, each of which had to be overcome in succession, if entrance was to be gained by other than frontal attack.

The great keep at Coucy was almost one hundred feet in diameter and 212 feet high. At the base its walls were eighteen to thirty-four feet thick and formed a storage vault for supplies. Successive floors produced a soldiers' hall, a Great Hall with galleries, special quarters for the noble's family and, finally, a "fighting-top." One understands the use of the words *ingenium* and *ingeniator* when he studies the details of these remarkable constructions.*

Another factor then entered the engineering field which brought this era to a close and, at the same time, gave wider use to the term engineer. The origin of gunpowder seems to be shrouded in mystery. It was known to the alchemists of the 13th and was used in firing cannon in the 14th Centuries. With its advent, attack once again gained superiority over defense. It sounded the death knell of the medieval castle. It gave emphasis to a new

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* The ten volumes of Violett-le-Duc's monumental *Dictionnaire Raisonne de l'Architecture Française du XI^e and XVI^e Siecle*, Paris, B. Bauge, 1854, is a standard work on medieval construction and a mine of information on the activities of the medieval *ingeniator*.

technique in the work of the ancient master builder, and, as has always been the case, the birth of a new technique, unrelated to earlier or current practice, led to the branching off from the parent stem of a new profession, in this case military engineering.

We are apt to forget the importance of gunpowder in the history of engineering. Much of the older practice of civil or building construction was superseded by a new and specialized military design, the earthwork fortification. The old castle, both a fortress and a home, was no longer worth building. The casting of cannon gave new impetus to the metallurgical art. Problems of range and elevation led to a deluge of books on military surveying and encouraged the development of surveying instruments. The mysteries of trajectory attracted the attention of the mathematically inclined and the inventive devised new "engines" and mechanisms. These were notable developments in the history of our profession. Furthermore, it is only in recent years that we have begun to lose some of the effects of these strongly military beginnings and traditions in engineering practice. Like the great military leaders of the past the engineers of the last generation led their forces in the field, on surveys and in construction, and relied on an esprit de corps, on the élan that comes from team-work in meeting and overcoming obstacles, to push their jobs through. We must see to it, in these modern days of functionalized organization, and the endless division of authority, that our younger engineers retain some of this spirit of team-work and service which is traditionally characteristic of our great profession.

Thus the Middle Ages came to an end with the advent of gunpowder, which gave birth to military engineering as a separate profession and was also a powerful factor in the rise of more democratic institutions, of town life and a public consciousness. The process was not altogether easy and pleasant but a common soldier, armed with a blunderbuss, was more than a match for the noble in his costly armor, and the older restrictions of the Middle Ages soon began to disappear. Similarly, the Reformation brought to an end an era in which the church, struggling to build the City of God, had substituted for a public consciousness that simply did not exist, and had fathered man's greatest structural achievement in stone, the skeleton-stone construction of the Gothic cathedral.

The Renaissance, as modern historians point out, was not a new-birth as the name implies, but the flowering of a long period of development under the new atmosphere of hope and progress that followed the Middle Ages. The times were ripe for achievement, a rebirth of public engineering, which was to be carried forward, especially in France where leadership in engineering rested all through the 17th and 18th Centuries.

It is interesting to speculate on the position and changing fortunes of the engineer during these centuries. It seems clear that, during Roman Times, the real master-builders were usually the Roman officials themselves. There were, of course, many technical subordinates, surveyors, levellers, quantity surveyors, water superintendents, etc., but such political leaders as Appius Claudius knew and understood the relatively few possibilities and basic requirements of current construction and could father and direct such public constructions as aqueducts,

roads, bridges and tunnels. Both the emperors Trajan and Hadrian were, apparently, quite skilled in design, and that the former knew his engineering is clearly demonstrated in the Pliny-Trajan letters.

All of this passed out with the fall of Rome and the master-builders and *ingeniators* of the Middle Ages seem, from the little we know of them, to have been independent itinerant craftsmen passing from job to job over quite wide areas. The notebook of one of them, Wilars de Honecort, of about 1240 A.D., has survived and gives us some idea of the interests of one of the master craftsmen who, presumably, were responsible for the construction work of the period. De Honecort had been all over France from Rheims and Laon, Meaux and Chartres, to Lausanne and also in Hungary. His sketches are crude and rough but include notes of various items from bits of cathedral design to engines of war, and from machines for boring of logs for water pipes to problems in military surveying.

Unfortunately we know nothing of the actual procedures in the design of the cathedrals, fortresses or bridges of the Middle Ages. No plans now exist if, indeed, more than pictorial sketches were ever made. Scale models were, apparently, in some use at a later date but their earlier use is purely speculative. Yet that some fairly clear and complete pre-construction planning was involved in major structures at least seems certain.

Much the same observation as to the status of the engineer would also apply to the Renaissance. The contribution of Leonardo da Vinci to the evolution of engineering has been greatly over-painted. Remarkable genius as he was, the conditions under which he lived and worked made it practically impossible for him to exercise any constructive leadership in professional progress. A letter of application for a job, written about 1484 to the Duke of Milan, reveals very clearly the position of the engineer in Leonardo's day. He was an independent expert who sought for himself a precarious attachment to this or that political boss or military leader who happened, at the moment, to be near the top of the heap. Leonardo offered his "secrets" for hire, he emphasized, in particular, his skill in designing and building military devices, but he also claimed ability as a designer of buildings, as an artist and sculptor and "in conducting water from one place to another." He served one leader and, upon his eclipse, sought another patron, dying in France where he had gone in the train of Francis I.

While the term engineer was coming into use, it is clear that there was, in Leonardo's day, no sharp distinction in the practice of military engineering and architecture or civil engineering. In fact, military engineers were sometimes called upon to undertake civil works even as late as the period of Vauban (1633–1706) while men with native talent in construction also promoted and carried out civil undertakings although such works were, apparently, regarded as being more closely allied to architecture in nature.

The final split between civil and military engineering may be said to date from John Smeaton (1724–1792) who, about 1750, began to refer to himself as a civil engineer in order to distinguish his field from that of the military worker. The break between civil engineering and architecture in France, then the leading country in

engineering activity, however, was not complete until the 19th Century when the advent of science in engineering led to the parting of the ways, for the architect did not adopt this new technique but continued to emphasize the aesthetic approach in design.

Finally, it should be noted that it is to another military man, Vauban, the great military engineer of the period of Louis XIV, that we are indebted for the first steps toward bringing engineers together as a group and thus securing for them some professional standing and official recognition. It was Vauban who proposed about 1672 that the army engineers, who were even then, like Leonardo and earlier workers, attached in a more or less personal capacity as aides and consultants to the various military leaders, should be made a special branch of the service.

Even this very brief review of some of the developments of the Middle Ages which were not clearly developed in Professor Draffin's study, suffices, we believe, to make clear that the Middle Ages were not a sterile and unimportant era in engineering history. They gave our profession its name, they gave us a tradition of devotion to duty and service, they gave us ingenious and remarkable engines of war and the medieval castle, and a few notable bridges; they also gave us what will probably remain as man's greatest achievement in stone construction, the Gothic cathedral, for the age of stone masonry has passed.

New Members

ALLEN, PERCIVAL R., Instructor in Physics, Wentworth Institute, Boston, Mass. C. W. Banks, C. W. Tudbury.

AMISS, JOHN M., Director, Industrial Education, Chrysler Corp., Detroit, Mich. C. J. Freund, J. Gerardi.

AUSTIN, ALLEN A., Lecturer in Engineering, University of California, Los Angeles, Calif. L. M. K. Boelter, W. E. Mason.

BAHRMAN, GEORGE E., Instructor in Mathematics, Michigan College M. & T. Houghton, Mich. J. M. Harrington, W. A. Longacre.

BOYD, H. SHANNON, Instructor in T. & A. M., Iowa State College, Ames, Iowa. H. J. Gilkey, S. J. Chamberlain.

CAMERON, CHARLES F., Associate Professor of Electrical Engineering, Oklahoma A. & M. College, Stillwater, Okla. A. Naeter, E. R. Stapley.

COKE, JOHN M., Assistant Professor of Mechanical Engineering, Colorado School of Mines, Golden, Colo. W. M. Richtmann, J. R. Morgan.

CONKLIN, WILLET T., Instructor in English, University of Texas, Austin, Texas. W. R. Woolrich, C. E. Rowe.

COWING, GUY R., Assistant Director, General Motors Institute, Flint, Mich. Albert Sobey, C. A. Brown.

CROUCH, JOEL E., Associate Professor of Industrial Engineering, The Pennsylvania State College, State College, Pa. Re-admission.

DANIEL, LEE, Instructor in Engineering Drawing, University of Notre Dame, Notre Dame, Ind. C. C. Stevason, W. W. Turner.

DONAHEY, MICHAEL H., Instructor in Civil Engineering, Yale University, New Haven, Conn. Hardy Cross, C. W. Dunham.

DUBOIS, RALPH N., Chief Experimental Engineer, Aircraft Engine Div., Packard Motor Car Co., Toledo, Ohio. C. J. Freund, T. C. Hanson.

DUNLAP, L. T., Associate Professor of Mathematics, The Pennsylvania State College, State College, Pa. F. W. Owens, H. A. Everitt.

ERDOSS, BELA K., Assistant Professor of Mechanical Engineering, Lehigh University, Bethlehem, Pa. F. V. Larkin, M. C. Stuart.

GASKELL, ALFRED S., Instructor in Engineering Drawing, Iowa State College, Ames, Iowa. H. J. Gilkey, O. A. Olson.

HOOK, WARREN H., Associate Professor of Heat Power Engineering, Cornell University, Ithaca, N. Y. F. O. Ellenwood, W. R. Cornell.

LAUCHLAND, LYMAN S., Assistant Professor of Electrical Engineering, University of Toronto, Toronto, Ont. R. F. Leggett, C. R. Young.

LINDAU, JULES W., Associate Professor of Mechanical Engineering, University of South Carolina, Columbus, S. C. R. L. Sumwalt, G. S. Rosselot.

LITMAN, SAMUEL, Associate Professor of Electrical Engineering, University of South Carolina, Columbia, S. C. R. L. Sumwalt, G. A. Rosselot.

LOUGH, EDWIN B., Field Representative Techincal Publications, D. Van Nostrand Co., 2260 Pelham Ave., Los Angeles, Calif. W. R. Woolrich, C. L. Svensen.

MICHALOS, JAMES P., Assistant Professor of Civil Engineering, Montana State College, Bozeman, Mont. Hardy Cross, E. W. Schilling.

MULLER, HENRY N., Manager, Graduate Student Training, Westinghouse Electric Corps., East Pittsburgh, Pa. J. E. Hobson, A. J. Allen.

NORMAN, CLARENCE C., Assistant Professor of Civil Engineering, Clemson College, Clemson, S. C. S. R. Rhodes, S. B. Earle.

ORR, WESLEY L., Associate Professor of Engineering, University of California, Los Angeles, Calif. J. W. Hazen, W. E. Mason.

PALMER, LEWIS G., Instructor in Drawing, University of Minnesota, Minneapolis, Minn. H. C. T. Eggers, H. D. Myers.

PAUL, WM. HOWARD, Professor of Automotive Engineering, Oregon State College, Corvallis, Ore. G. W. Gleeson, W. H. Martin.

PETERSON, MASON M., Assistant Professor of Electrical Engineering, Cornell University, Ithaca, N. Y. A. B. Credle, J. H. Smith.

PITMAN, JAMES H., Chairman, English Dept. (Humanistic Div.), Newark College of Engineering, Newark, N. J. F. D. Garvin, H. E. Walter.

PORTEOUS, JOHN W., Associate Professor of Electrical Engineering, University of Alberta, Edmonton, Canada. R. S. L. Wilson, F. L. Bishop.

ROBERTS, EARL, Instructor in Mathematics, Michigan College of M. & T., Houghton, Mich. W. A. Longacre, F. L. Partlo.

ROBERTS, ENOS A., Assistant Professor of Accounting, University of Detroit, Detroit, Mich. C. J. Freund, H. J. McAuley.

ROGERS, WILLARD L., Instructor in Mechanical Engineering, Iowa State College, Ames, Iowa. H. A. Birkness, H. J. Stoever.

RUSZAJ, NORBERT F., Instructor in Aeronautical Engineering, University of Minnesota, Minneapolis, Minn. J. D. Akerman, G. L. VonEschen.

SCHJONBERG, CARL S., Assistant Professor of Electrical Engineering, Michigan College of M. & T., Houghton, Mich. G. W. Swenson, W. C. Polkingham.

SCHOLES, SAMUEL R., Professor of Glass Technology, New York State College of Ceramics, Alfred, N. Y. M. E. Holmes, C. R. Amberg.

SCHWARTZ, MORRIS C., Assistant Professor of Chemical Engineering, Louisiana State University, Baton Rouge, La. L. J. Lassalle, H. W. Waterfall.

SCHOENHERR, KARL E., Dean of Engineering, University of Notre Dame, Notre Dame, Ind. R. J. Schubmehl, W. W. Turner.

SIEBERT, CLARENCE A., Associate Professor of Chemical and Metallurgical Engineering, University of Michigan, Ann Arbor, Mich. A. H. White, J. T. Banchero.

SIGERFOOS, CHARLES C., Associate Professor of Mechanical Engineering, Michigan State College, East Lansing, Mich. L. G. Miller, L. C. Price.

SMITH, HENRY J., Instructor in Electrical Engineering, Southern Methodist University, Dallas, Texas. E. H. Flath, Sophus Thompson.

SPANGENBERG, KARL R., Associate Professor of Electrical Engineering, Stanford University, Stanford University, Calif. E. L. Grant, D. W. Young.

SPRINGER, EDWIN K., Assistant Professor of Mechanical Engineering, University of Wisconsin, Madison, Wis. L. A. Ireson, F. E. Johnson.

SPRINGER, RICHARD D., Instructor in Drawing, University of Minnesota, Minneapolis, Minn. H. D. Myers, H. C. T. Eggers.

STEARNS, STEPHEN R., Assistant Professor of Civil Engineering, Thayer School of Engineering, Hanover, N. H. J. M. Hirst, E. S. Brown.

TURRITTIN, HUGH L., Assistant Professor of Mathematics and Mechanics, University of Minnesota, Minneapolis, Minn. R. F. Schuck, O. W. Potter.

VARNER, WM. R., Associate Professor of Physics, Oregon State College, Corvallis, Ore. G. W. Gleeson, A. L. Albert.

WARNER, CECIL F., Instructor in Mechanical Engineering, Purdue University, Lafayette, Ind. A. A. Potter, H. L. Solberg.

WATSON, SAMUEL M., Assistant Professor of Mechanical Engineering, Clemson College, Clemson, S. C. B. E. Fernow, S. B. Earle.

WEBER, JOHN C., Assistant Professor of Electrical Engineering, West Virginia University, Morgantown, W. Va. C. B. Siebert, E. C. Jones.

WECKLER, H. L., Vice President and General Manager, Chrysler Corp., Detroit, Mich. C. J. Freund, J. Gerardi.

WILLIAMS, WILLIAM S., Assistant Professor of Drawing, University of Minnesota, Minneapolis, Minn. H. D. Myers, H. C. T. Eggers.

The following applications were received in this office in one day—Dec. 10, 1945.

ANDERSON, ALBERT W., Associate Professor of Mechanical Engineering, University of Minnesota, Minneapolis, Minn. J. J. Ryan, H. K. Palmer.

DOWDELL, RALPH L., Professor of Metallurgy, University of Minnesota, Minneapolis, Minn. Re-admission. T. L. Joseph, W. H. Parker.

HEILIG, LOUIS S., Associate Professor of Mining, University of Minnesota, Minneapolis, Minn. T. L. Joseph, W. H. Parker.

HUGHES, THOMAS P., Assistant Professor of Mechanical Engineering, University of Minnesota, Minneapolis, Minn. J. J. Ryan, H. K. Palmer.

JAHN, WILLIAM E., Instructor in Mechanical Engineering, University of Minnesota,

Minneapolis, Minn. J. J. Ryan, H. K. Palmer.

JOHNSTON, MILAN A., Assistant Professor of Mechanical Engineering, University of Minnesota, Minneapolis, Minn. H. Laitala, J. J. Ryan.

JORDAN, RICHARD C., Associate Professor and Asst. Head, Dept. Mechanical Engineering, Univ. Minnesota, Minneapolis, Minn. J. J. Ryan, H. K. Palmer.

LAJOY, MILLARD H., Assistant Professor and Asst. Dir. Eng. Exp. Station, University Minnesota, Minneapolis, Minn. J. J. Ryan, H. A. Doeringsfeld.

LAMBERT, EDWIN M., Professor of Mining, University of Minnesota, Minneapolis, Minn. T. L. Joseph, W. H. Parker.

LARSEN, OTIS M., Instructor in Mechanical Engineering, University of Minnesota, Minneapolis, Minn. H. K. Palmer, J. J. Ryan.

LEE, ADOLPH O., Assistant Professor of Mechanical Engineering, University of Minnesota, Minneapolis, Minn. J. J. Ryan, H. K. Palmer.

MADDEN, ARTHUR J., Instructor in Chemical Engineering, University of Minnesota, Minneapolis, Minn. C. S. Mann, S. C. Lind.

MARTIN, ALLAN E., Assistant Professor of Metallurgy, University of Minnesota, Minneapolis, Minn. T. L. Joseph, W. H. Parker.

MCEWEN, WM. R., Assistant Professor of Mathematics and Mechanics, University of Minnesota, Minneapolis, Minn. H. A. Doeringsfeld, G. L. Von Eschen.

MOORE, JOHN W., Instructor in Mechanical Engineering, University of Minnesota, Minneapolis, Minn. J. J. Ryan, H. K. Palmer.

MUNRO, WILLIAM D., Instructor in Mathematics and Mechanics, University of Minnesota, Minneapolis, Minn. H. A. Doeringsfeld, G. L. Von Eschen.

SCHROEPFER, GEORGE J., Professor of Sanitary Engineering, University of Minnesota, Minneapolis, Minn. A. S. Cutler, C. S. Mann.

SOLBERG, LAWRENCE A., Instructor in Mechanical Engineering, University of Minnesota, Minneapolis, Minn. J. J. Ryan, H. K. Palmer.

WARSCHAWSKI, STEFAN E., Professor of Mathematics and Mechanics, University of Minnesota, Minneapolis, Minn. H. A. Doeringsfeld, G. L. Von Eschen.

19 from University of Minnesota.

DRAKE, GERTRUDE G., Instructor in Language,, Michigan College of M. & T., Houghton, Mich. F. L. Partlo, W. A. Longacre.

MACHOVINA, PAUL E., Assistant Professor of Engineering Drawing, Ohio State University, Columbus, Ohio. R. S. Paffenbarger, C. D. Cooper.

MARSCHKER, F. W., Sales Manager, New Departure Div., General Motors Corp., Detroit, Mich. C. J. Freund, F. C. Hanson.

PEARSON, JOHN R., Assistant Professor of Mechanical Engineering, Robert College, Istanbul, Turkey. C. P. Bliss, W. H. Jones.

SCHLECHTEN, ALBERT W., Associate Professor of Mining and Metallurgical Engineering, Oregon State College, Corvallis, Ore. G. W. Gleeson, A. L. Albert.

SULLIVAN, JOSEPH M., Assistant Employment Manager, Detroit Edison Co., Detroit,, Mich. C. J. Freund, F. C. Hanson.

ZEDER, FRED M., Vice Chairman of Board, Chrysler Corp., Detroit, Mich. C. J. Freund, J. Gerardi.

191 new members this year.

College Notes

Dean S. S. Steinberg of the College of Engineering of the **University of Maryland** has returned from his good-will tour of Latin America, where he made a survey of engineering schools in the other American republics on a trip sponsored by the Department of State. He visited institutions and conferred with engineers in Colombia, Ecuador, Peru, Chile, Argentina, Uruguay, Brazil, Venezuela, Panama, Costa Rica, Mexico, and Cuba.

The other purposes of his trip were to establish closer relations between the engineering educators of Latin America and those of the United States, as well as between their respective engineering societies; to arrange for exchange of professors; and to provide for a wider interchange of engineering and technical literature.

For this trip Dean Steinberg was designated the Official Representative of the Society for the Promotion of Engineering Education whose membership includes all engineering colleges in the United States and Canada; and Official Representative of the American Society of Mechanical Engineers, as well as the American Society of Civil Engineers.

During the course of his trip Dean Steinberg was made an Honorary Professor of the University of Ecuador; an Honorary Member of the Cultural Institute of Ecuador; and Special Representative to the United States of the Union of South American Engineering Associations, as well as of the Association of Engineers and Architects of Mexico.

William S. LaLonde, Jr., who recently rejoined the faculty of **Newark College of Engineering** after four and a half years service in the Navy, has been named chairman of the Civil Engineering Department. Professor LaLonde held the rank of commander in the Naval Reserve at the time of his discharge.

Another recent appointment is that of Professor William Hazell, Jr., who has been made associate dean and director of admissions. He was formerly an assistant professor in physics.

Edison Medal Awarded to Philip Sporn

The Edison Medal for 1945 has been awarded by the American Institute of Electrical Engineers to Philip Sporn, executive vice-president, American Gas & Electric Service Corporation, "For his contributions to the art of economical and dependable power generation and transmission."

The medal was presented to Mr. Sporn at the Winter Convention of the American Institute of Electrical Engineers.

Physics Column

Your committee is working on the program for the big meeting in St. Louis. One of the sessions in conjunction with the American Association of Physics Teachers will be devoted to a consideration of the place of physics courses in the curricula of the technical institutes which are being sponsored by the S.P.E.E. Some of the leading engineering administrators of the technical institute program will participate in the session. The session of the two groups of physicists with the Division of Engineering Mechanics will concentrate on ways and means of bringing together the methods of approach in presenting the fundamentals of mechanics in physics courses and in courses in engineering mechanics. It is hoped that long needed reforms will stem from this session.

A communication has been received through F. L. Partlo, head of the physics department that "The Michigan College of Mining and Technology has been added to its eight engineering degrees a ninth, in Engineering Physics, and to its three degrees in science a fourth, in Physics. Both changes are effective immediately. For the present, the new curricula will be in the undergraduate field only. In offering work in engineering physics, M. C. M. T. joins a relatively small but increasing number of technical schools."

A new revised physics curriculum has also been received from J. S. Thompson, head of the physics department of Illinois Institute of Technology.

Readers of this column are reminded that the column can carry news only in-so-far as they personally contribute it. Kindly address contributions to the chairman at the A. & M. College of Texas.

J. G. Potter,
Chairman

Enrollment of Undergraduate Civilian Engineering Students, as of November 5, 1945

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3d year)			Seniors (4th year)			5th Year (of 5-yr. Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1944–45		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Aeronautical	1152	30	410	490	49	293	269	20	158	223	10	59	9	—	1	3	1	9	112	6	18	2258	116	948	213	7	4
Agricultural	162	2	21	59	1	19	40	3	16	16	2	3	—	—	—	18	—	1	—	—	—	295	8	60	16	—	1
Architectural	331	56	157	222	43	89	75	30	38	56	20	11	12	6	8	3	1	—	7	—	3	706	156	306	31	6	6
Ceramic	62	7	22	35	5	19	28	3	6	21	2	4	—	—	—	2	—	2	—	—	—	148	17	53	13	—	—
Chemical	2083	80	543	1166	32	438	753	70	259	566	32	150	16	1	4	28	2	24	553	71	44	5165	288	1462	740	15	12
Civil	2169	31	697	1007	30	504	768	31	287	550	11	153	20	—	3	61	1	18	488	9	53	5063	113	1715	621	2	21
Electrical	3464	52	1471	1746	60	811	1155	34	377	752	19	178	22	—	2	51	1	34	758	19	88	7948	185	2961	827	8	19
General	966	13	232	326	6	120	64	3	13	141	1	14	—	—	—	11	—	8	362	31	14	1870	54	401	345	6	13
Industrial	309	3	97	193	5	97	155	3	59	87	—	23	1	—	1	2	—	1	363	20	66	1110	31	344	72	3	1
Mechanical	3518	67	1496	2001	64	1102	1499	33	641	1054	18	301	37	1	2	60	—	37	1037	21	110	9206	204	3689	1318	5	48
Metallurgical	142	2	68	91	1	67	102	2	68	89	1	37	4	—	1	16	—	—	119	2	8	563	8	249	130	1	2
Mining	103	—	62	66	2	47	64	—	38	48	1	21	—	—	—	9	—	—	1	—	—	291	3	168	62	—	—
Naval Arch. & Marine	36	—	1	15	1	6	21	—	4	12	—	2	—	—	—	1	—	1	—	—	—	85	1	14	15	—	—
Petroleum	474	4	185	170	1	70	72	—	33	42	—	23	1	—	2	5	—	1	—	—	—	764	5	314	46	—	—
Unclassified	9443	210	4456	721	76	489	297	20	121	149	5	64	11	1	2	12	5	59	2872	295	493	13505	612	5684	88	3	3
Totals	24414	557	9918	8308	376	4171	5362	252	2118	3806	122	1043	133	9	26	282	11	195	6672	473	897	48977	1801	18368	4537	56	131

Enrollment of Undergraduate Civilian Engineering Students, as of November 5, 1945—Continued

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3d year)			Seniors (4th year)			5th Year (of 5-yr. Curriculum)			Special Students			Evening Students			Totals			No. of
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	

Enrollment of Undergraduate Civilian Engineering Students, as of November 5, 1945—Continued

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3d year)			Seniors (4th year)			5th Year (of 5-yr. Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1944–45		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Akron	62	4	38	—	—	1	1	—	3	2	—	—	2	—	—	—	—	—	1	—	—	68	4	42	1	—	—
Ala. Poly	427	9	103	102	7	27	42	4	16	24	5	10	—	—	—	5	—	—	—	—	—	600	25	156	—	—	—
Ala. Uni	169	7	63	35	1	16	15	2	7	13	—	4	—	—	—	2	—	2	37	2	12	271	12	104	27	1	1
Alaska	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Alfred	25	4	6	9	4	2	8	—	2	1	—	1	—	—	—	1	—	1	—	—	—	44	8	12	5	—	—
Arizona	121	2	33	34	2	13	32	3	15	14	—	8	—	—	—	11	—	4	—	—	—	212	7	73	7	1	—
Arkansas	127	2	44	30	2	17	22	—	12	11	—	2	—	—	—	—	—	—	—	—	—	190	4	75	13	—	—
Bradley	35	2	11	17	—	8	2	—	—	1	—	—	—	—	—	—	—	1	—	—	—	55	2	20	3	—	—
Brooklyn	134	1	82	95	1	37	23	—	15	24	—	5	—	—	—	2	1	—	974	39	182	1251	42	321	86	—	2
Brown	83	—	34	19	3	9	10	5	7	9	1	4	—	—	—	—	—	—	—	—	—	121	9	54	8	—	—
Bucknell	70	2	28	13	1	3	14	2	7	13	2	8	—	—	—	1	—	—	—	—	—	111	7	46	3	—	—
Calif. Tech	104	—	34	11	—	15	11	—	6	13	—	6	—	—	—	—	—	—	—	—	—	139	—	61	—	—	—
Calif. Uni	289	4	66	124	11	17	267	5	24	130	3	11	—	—	—	—	—	—	—	—	—	811	23	117	128	1	—
Calif. U. at L. A	186	4	73	66	3	29	29	3	15	3	—	—	—	—	—	29	—	16	—	—	—	313	10	132	—	—	—
Calif. Uni. So	91	3	220	39	3	85	35	4	71	32	—	24	—	—	—	—	—	—	—	—	—	197	10	400	—	—	—
Carnegie	271	1	95	66	3	38	52	—	26	33	—	8	—	—	—	10	—	—	398	11	51	830	15	218	44	—	—
Case	149	5	172	49	—	62	23	1	27	39	3	6	—	—	—	19	1	—	577	31	43	856	41	310	50	1	—
Catholic	43	8	15	16	—	7	15	2	12	11	—	4	—	—	—	11	—	—	—	—	—	96	10	38	10	1	—
Cincinnati	283	17	205	87	16	46	41	13	7	30	—	8	9	—	3	—	—	—	8	—	—	458	46	269	32	—	—
Citadel	40	—	3	21	—	2	9	—	—	7	—	—	—	—	—	—	—	—	—	—	—	77	—	5	—	—	—
Clarkson	123	—	141	46	—	27	17	—	11	21	—	3	—	—	—	—	—	—	—	—	—	207	—	182	17	—	—
Clemson	435	—	71	83	—	34	25	—	15	10	—	17	—	—	—	—	—	—	—	—	—	553	—	137	13	—	3
Colo. A. & M	30	1	30	10	1	18	3	—	5	5	—	2	—	—	—	—	—	—	—	—	—	48	2	55	—	—	—
Colo. Mines	86	—	55	21	—	15	18	—	16	9	—	2	—	—	—	—	—	—	—	—	—	134	—	88	28	—	—
Colo. Uni	153	12	201	49	10	76	33	9	42	17	2	21	—	—	—	2	—	—	—	—	—	255	33	340	16	1	—
Columbia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Connecticut	90	2	34	18	2	10	13	1	7	3	—	4	—	—	—	—	—	—	—	—	—	124	5	55	20	—	—
Cooper	56	5	16	32	1	4	10	—	2	7	3	1	11	1	2	—	—	—	191	6	42	307	16	67	33	—	—
Cornell	369	21	176	125	7	82	45	6	39	39	2	27	2	1	1	10	—	4	—	—	—	590	37	329	—	—	—

Enrollment of Undergraduate Civilian Engineering Students, as of November 5, 1945—Continued

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3d year)			Seniors (4th year)			5th Year (of 5-yr. Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1944-45		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Dayton	46	—	17	24	1	4	9	1	2	7	—	2	—	—	—	2	—	1	38	—	3	126	2	29	8	—	—
Delaware	48	—	11	7	1	7	1	1	2	5	—	2	—	—	—	—	—	—	—	—	—	61	2	22	7	—	—
Denver	82	4	49	29	5	13	8	—	4	3	—	2	—	—	—	—	—	—	—	—	—	122	9	68	6	1	—
Detroit	165	3	40	107	3	16	42	—	21	21	1	10	19	—	4	—	—	—	34	1	—	378	8	91	18	—	—
Drexel	289	15	97	63	4	18	37	3	8	29	1	3	4	—	—	14	—	—	—	—	—	436	24	126	25	—	—
Duke	60	—	21	21	1	6	10	2	8	7	2	4	—	—	—	—	—	—	—	—	—	98	5	39	53	—	—
Penn	42	2	15	5	1	12	5	—	3	3	—	2	6	—	1	2	1	—	292	21	41	355	25	74	22	—	—
Florida	—	—	—	*190	1	100	12	1	5	12	—	2	—	—	—	—	—	—	—	—	—	214	2	107	43	—	—
Geo. Wash.	143	12	19	38	—	1	22	1	4	17	—	—	—	—	—	1	—	12	162	11	9	383	13	46	16	—	—
Ga. Tech	432	—	177	135	—	134	49	—	55	54	—	27	1	—	1	5	—	6	205	—	74	881	—	474	109	—	7
Harvard Coll.	—	—	—	8	—	—	2	—	—	1	—	—	9	—	—	—	—	—	—	—	—	20	—	—	—	—	36
Haverford	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hawaii	56	1	—	3	—	—	8	—	—	1	—	—	—	—	—	—	—	—	—	—	—	96	1	—	3	—	—
Howard	28	1	11	19	—	3	6	—	1	4	1	—	—	—	—	—	—	—	8	1	—	65	3	15	5	—	—
Idaho	33	—	28	10	—	5	6	—	8	5	—	2	—	—	—	—	—	—	—	—	—	54	—	43	11	—	—
Ill. Tech.	228	6	232	156	5	105	253	—	54	47	2	21	—	—	—	17	1	—	944	197	181	1645	211	593	117	—	—
Illinois U.	677	12	91	219	11	37	128	6	16	70	3	6	—	—	—	—	—	—	—	—	—	1101	32	420	49	1	2
Iowa St. Coll.	290	15	166	103	8	—	24	—	—	17	2	—	—	—	—	20	1	—	—	—	—	620	26	166	76	2	—
Iowa Uni.	60	1	33	34	2	14	16	2	10	7	—	6	—	—	—	—	—	—	—	—	—	117	5	63	7	—	—
Johns Hopkins	102	—	46	33	—	8	21	—	5	9	—	1	—	—	—	6	—	—	379	43	44	550	43	103	5	—	—
Kansas St. Coll.	111	—	63	30	2	29	9	2	20	9	—	18	—	—	—	3	—	11	—	—	—	162	4	141	12	—	3
Kansas Uni.	136	7	81	39	7	42	17	1	38	14	3	10	—	—	—	—	—	—	—	—	—	206	18	171	25	—	—
Kentucky	115	1	52	25	8	7	6	6	6	1	—	2	—	—	—	—	—	—	—	—	—	147	15	67	8	1	—

* Fr. & Soph.

Enrollment of Undergraduate Civilian Engineering Students, as of November 5, 1945—Continued

* Fr. & Soph.

Enrollments of Undergraduate Civilian Engineering Students, as of November 5, 1943—Continued

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3d year)			Seniors (4th year)			5th Year (of 5-yr. Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1944-45		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Lafayette	90	—	—	11	—	—	20	—	—	3	—	—	—	—	—	—	—	—	—	—	—	124	—	—	10	—	—
Lehigh	289	—	82	97	—	46	47	—	21	31	—	10	—	—	—	—	—	—	—	—	—	464	—	159	30	—	—
Louisiana	494	—	69	84	—	26	28	5	17	25	1	12	—	—	—	2	—	35	8	—	1	641	6	160	—	—	—
La. Poly	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
La. So. W.	136	1	45	42	—	16	7	1	1	9	—	3	—	—	—	—	—	—	—	—	—	194	2	65	5	—	—
Louisville	84	3	52	29	4	13	11	1	5	15	1	3	—	—	—	1	—	—	—	—	—	140	9	73	38	—	—
Maine	136	5	43	43	3	16	25	4	7	10	—	3	—	—	—	8	1	1	—	—	—	222	13	70	20	—	1
Manhattan	149	—	19	41	—	8	22	—	8	19	—	4	—	—	—	—	—	—	—	—	—	231	—	39	29	—	3
Marquette	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Maryland	86	1	38	21	—	13	13	1	1	14	—	4	8	1	—	2	1	6	—	—	—	144	4	62	11	—	—
Mass. Inst. Tech.	508	4	124	133	1	119	165	4	64	173	3	32	—	—	—	—	—	—	—	—	—	979	12	329	90	5	—
Mich. M. & T.	88	1	54	49	1	16	19	2	9	18	—	8	—	—	—	—	—	—	—	—	—	174	4	87	—	—	—
Mich. St. Coll.	214	6	—	17	—	—	28	1	—	18	—	—	—	—	—	—	—	—	—	—	—	275	7	—	21	—	—
Mich. Uni.	222	16	165	124	17	174	84	8	85	77	3	43	—	—	—	8	—	19	—	—	—	515	44	486	105	1	—
Minnesota	304	21	250	109	11	117	49	8	37	54	8	32	—	—	—	—	—	—	718*	—	—	1234	48	436	97	—	—
Miss. St. Coll.	126	2	31	38	—	18	13	—	9	5	—	2	—	—	—	—	—	—	—	—	—	242	2	—	2	—	—
Miss. Uni.	27	1	17	5	1	3	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	32	2	23	—	—	—
Mo. Mines	123	1	38	35	3	7	34	2	11	32	2	4	—	—	—	1	1	7	1	14	1	226	23	68	51	—	1
Missouri Uni.	218	1	54	27	2	26	14	—	9	3	—	9	—	—	—	—	—	—	—	—	—	262	3	98	14	2	1
Mont. St. Coll.	80	4	45	9	3	16	10	3	11	6	—	1	—	—	—	—	—	—	—	—	—	105	10	73	7	—	—
Mont Mines	7	3	11	3	1	6	2	—	3	1	—	5	—	—	—	—	—	—	—	—	—	13	4	26	3	—	1
Nebraska	251	1	66	45	1	7	20	—	—	17	—	—	—	—	—	—	—	—	—	—	—	334	2	73	49	1	20
Nevada	54	—	1	12	—	—	6	—	—	9	—	—	—	—	—	12	—	—	—	—	—	93	—	1	—	—	—
Newark	274	4	67	75	4	22	42	8	8	20	—	2	—	—	—	2	—	1	456	22	84	869	38	184	86	2	3
New Hampshire	82	5	26	26	11	20	9	1	2	4	3	6	—	—	—	—	—	—	—	—	—	121	20	54	8	2	25
N. Mex. A. & M.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
N. Mex. Mines	10	—	3	13	—	3	1	1	—	5	—	4	—	—	—	12	—	—	—	—	—	41	1	10	5	—	—
N. Mex. Uni.	62	5	39	6	2	10	7	—	6	5	—	5	—	—	—	1	—	2	—	—	—	81	7	62	26	—	—

* All groups.

Enrollment of Undergraduate Civilian Engineering Students, as of November 5, 1945—Continued

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3d year)			Seniors (4th year)			5th Year (of 5-yr. Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1944-45		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
New York City Coll.	803	37	24	250	22	35	128	13	26	102	7	16	—	—	—	—	—	6	290	27	23	1573	106	130	200	—	—
New York Uni.	187	—	91	103	—	43	123	—	63	39	—	6	—	—	—	—	—	—	427	20	67	879	20	270	115	—	—
N. Car. St. Coll.	524	—	—	145	—	—	38	—	8	41	—	5	—	—	—	—	—	—	—	—	—	748	—	13	38	—	—
N. Dak. St. Coll.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
N. Dak. Uni.	49	1	30	4	2	6	2	—	1	1	—	—	—	—	—	—	—	—	—	—	—	56	3	37	3	—	1
Northeastern	366	13	57	39	1	10	47	3	9	69	—	9	—	—	—	—	—	—	—	—	—	521	17	85	91	—	—
Northwestern	141	3	38	44	3	22	31	2	17	21	1	4	—	—	—	1	—	—	—	—	—	238	9	81	9	—	—
Norwich	33	—	18	7	—	2	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	34	—	18	—	—	—
Notre Dame	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ohio No. Uni.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ohio St. Uni.	468	21	88	189	13	33	75	5	9	32	1	2	3	1	—	—	—	—	130	9	—	897	50	132	77	4	—
Ohio Uni.	24	2	7	6	3	—	11	—	—	5	—	—	—	—	—	—	—	—	—	—	—	46	5	7	3	—	—
Okla. A. & M.	240	10	107	30	2	35	16	4	15	14	1	8	2	1	—	—	—	—	—	—	—	302	18	165	11	1	—
Okla. Uni.	101	7	63	101	10	41	54	3	23	43	1	14	—	—	—	—	—	—	—	—	—	299	21	141	142	—	—
Oregon	352	8	78	55	3	18	35	—	14	25	—	4	—	—	—	—	—	—	—	—	—	467	11	114	26	—	—
Pa. St. Coll.	587	4	234	210	2	86	96	2	44	59	2	14	—	—	—	—	—	3	—	—	—	952	10	356	189	4	—
Pennsylvania	26	—	24	8	—	14	2	—	—	3	—	2	—	—	—	—	—	—	—	—	—	39	—	40	12	—	—
Pittsburgh	156	4	145	38	2	10	36	—	5	28	1	—	—	—	—	—	—	—	228	—	—	486	7	160	26	1	—
Porto Rico	149	3	—	140	2	—	84	—	—	61	—	—	—	—	—	—	—	—	—	—	—	434	5	—	—	—	—
Pratt	54	1	52	19	5	18	11	2	7	10	1	8	—	—	—	—	—	—	—	—	—	94	9	85	25	—	—
Princeton	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Purdue	1203	47	834	474	21	322	231	15	164	277	4	118	—	—	—	13	1	8	—	—	—	2098	88	1446	113	3	—
Rensselaer	249	17	156	51	4	52	37	2	31	29	6	18	—	—	—	3	1	4	56	12	29	425	42	290	68	3	4
Rhode Island	102	—	—	20	2	—	7	2	—	5	1	—	—	—	—	—	—	—	—	—	—	135	5	—	11	1	—
Rice	87	—	2	32	3	5	7	—	—	11	1	2	—	—	—	—	—	—	—	—	—	137	4	9	9	—	—
Rochester	58	—	—	13	—	—	14	—	—	1	—	—	—	—	—	—	—	—	—	—	—	86	—	—	29	—	—
Rose	65	—	21	15	—	9	12	—	1	15	—	3	—	—	—	—	—	—	—	—	—	107	—	34	33	—	—
Rutgers	79	—	62	21	—	18	8	—	4	1	—	2	—	—	—	6	—	4	—	—	—	115	—	90	23	—	—

Enrollment of Undergraduate Civilian Engineering Students, as of November 5, 1945—Continued

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3d year)			Seniors (4th year)			5th Year (of 5-yr. Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1944-45		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
St. Louis Uni.	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
San Diego St. Coll.	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—
San Jose St. Coll.	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—
Santa Clara	39	—	15	15	—	5	6	—	1	3	—	1	—	—	—	—	—	—	—	—	—	63	—	22	6	—	—
Seattle	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
South Dakota St. Coll.	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
South Dakota Uni.	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Southern California	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Stanford	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Stevens Inst.	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Swarthmore	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Syracuse Uni.	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Tennessee	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Texas	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Texas A. & M.	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Texas Tech. Coll.	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Tri-State Coll.	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Tufts	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Tulane Uni.	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Union	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Utah	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Vanderbilt Uni.	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Villanova	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Virginia Mil. Inst.	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Virginia Poly. Inst.	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Virginia Uni.	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Wash. St. Coll.	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Wash. Uni.	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Wayne Uni.	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Webb Inst.	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Wentworth	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
West Va. Uni.	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Wichita Uni.	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Wisconsin	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Worcester	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—
Yale	124	1	46	39	1	15	19	—	6	15	—	3	—	—	—	—	—	—	—	—	—	197	2	70	19	—	—

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3d year)			Seniors (4th year)			5th Year (of 5-yr. Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1944–45		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Santa Clara	45	—	5	17	—	2	3	—	1	3	—	1	—	—	—	—	—	—	—	—	—	68	—	9	—	—	—
S. Car. Uni.	56	3	31	10	—	8	17	2	16	2	1	—	—	—	—	—	—	—	—	—	—	85	6	55	5	—	—
S. Dak. St. Coll.	33	1	15	10	—	12	2	—	2	1	—	—	—	—	—	1	—	—	—	—	—	47	1	29	9	—	—
S. Dak. Mines	71	—	29	23	1	12	5	—	2	6	—	—	—	—	—	—	—	—	—	—	—	105	1	43	9	—	—
So. Meth.	65	4	145	9	2	28	3	3	7	5	—	—	—	—	—	2	—	—	—	—	—	84	9	180	—	—	—
Stanford	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Stevens	216	—	72	86	—	21	6	—	3	11	—	2	—	—	—	—	—	—	—	—	—	319	—	98	199	—	—
Swarthmore	9	1	5	2	1	6	2	—	4	—	—	3	—	—	—	—	—	—	—	—	—	14	2	18	6	2	—
Syracuse	149	4	60	42	4	20	12	3	3	15	2	—	—	—	—	—	—	—	—	—	—	221	14	83	—	—	—
Tennessee	155	1	55	40	—	29	17	—	5	9	1	—	—	—	—	4	—	—	—	—	—	225	2	89	36	—	—
Tenn. Poly.	35	—	—	8	—	—	2	—	—	7	—	—	—	—	—	—	—	—	—	—	—	52	—	—	—	—	—
Texas A. & I.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Texas A. & M.	924	—	104	200	—	43	83	—	40	39	—	25	1	—	2	—	—	2	—	—	—	1247	—	216	31	—	2
Texas Mines	52	—	10	26	—	5	3	—	4	6	—	2	1	—	1	—	—	—	—	—	—	88	—	22	2	—	—
Texas Tech.	275	12	—	51	10	—	30	5	—	20	1	—	—	—	—	—	—	—	—	—	—	*376	28	—	13	2	—
Texas Uni.	678	14	296	303	14	148	151	10	65	48	3	17	4	—	3	—	—	—	—	—	—	1184	41	529	29	3	—
Thayer	43	—	8	8	—	5	13	—	8	—	—	—	—	—	—	—	—	—	—	—	—	64	—	21	2	—	—
Toledo	102	—	22	29	—	6	24	1	4	6	—	2	—	—	—	—	—	—	110	6	10	271	7	49	4	—	1
Tufts	69	4	50	8	—	15	6	2	8	4	1	5	—	—	—	—	—	—	—	—	—	87	7	78	72	1	—
Tulane	119	3	67	43	—	15	20	1	5	9	2	3	—	—	—	—	—	—	—	—	—	191	6	99	24	1	—
Tulsa	131	3	100	29	2	4	8	1	3	8	—	1	—	—	—	4	1	—	—	—	—	180	7	106	7	—	—
U. S. Coast Guard	134	—	—	88	—	—	—	—	—	106	—	—	—	—	—	10	—	—	—	—	—	338	—	—	97	—	—
Union	41	—	12	8	—	10	5	—	1	4	—	1	—	—	—	1	—	—	—	—	—	59	—	24	8	—	—
Utah. Ag.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Utah. Uni.	219	3	13	67	—	11	40	—	6	15	—	—	—	—	—	—	—	—	—	—	—	341	3	80	17	—	—
Vanderbilt	68	3	24	21	2	10	6	—	5	7	1	5	—	—	—	2	—	—	—	—	—	104	6	44	8	1	1
Vermont	17	3	15	6	1	4	—	—	3	—	1	1	—	—	—	—	—	1	—	—	—	23	5	27	6	1	—
Villanova	150	—	52	22	—	18	15	—	8	11	—	6	—	—	—	—	—	—	—	—	—	198	—	84	—	—	—
Va. Mil.	142	—	—	11	—	2	25	—	3	7	—	1	—	—	—	—	—	—	—	—	—	185	—	6	4	—	1

* Veterans included.

Enrollment of Undergraduate Civilian Engineering Students, as of November 5, 1945—Continued

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3d year)			Seniors (4th year)			5th Year (of 5-yr. Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1944–45		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Va. Poly	306	8	35	64	3	23	28	5	12	21	2	6	—	—	—	1	—	1	—	—	—	419	18	77	72	1	3
Virginia	23	—	13	5	—	13	7	—	4	1	—	2	—	—	—	—	—	—	—	—	—	36	—	32	—	—	—
Wash. U. (St. Louis)	150	3	86	38	—	20	29	1	6	12	1	4	—	—	—	—	—	—	—	—	—	229	5	116	44	—	—
Wash. Uni.	504	9	149	121	5	54	283	3	33	158	4	17	—	—	—	—	—	—	—	—	—	1066	21	253	—	—	—
Wash. St. Coll.	105	2	23	35	3	14	24	3	5	18	3	4	—	—	—	—	—	—	—	—	—	182	11	46	—	—	—
Wash. & Jeff.	32	—	—	7	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	40	—	—	0	—	—
Wayne	101	9	45	32	6	16	27	4	7	18	—	5	1	—	1	3	1	25	—	—	—	182	20	99	22	—	1
Webb Inst.	9	—	—	1	—	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	11	—	2	4	—	—
W. Va. Uni.	80	1	19	23	4	15	12	2	3	11	1	7	—	—	—	1	—	5	—	—	—	127	8	49	14	—	—
Wisconsin	158	6	204	152	16	96	289	2	41	119	3	17	—	—	—	—	—	—	—	—	—	718	27	358	91	1	—
Worcester	164	—	40	32	—	12	23	—	11	10	—	3	—	—	—	—	—	—	—	—	—	229	—	66	14	—	—
Wyoming	90	1	32	31	—	13	19	3	10	9	—	5	—	—	—	1	—	—	—	—	—	150	4	60	11	—	3
Yale	175	—	—	72	—	45	62	—	36	38	—	19	—	—	—	6	—	4	—	—	—	353	—	104	16	—	—
Canadian Schools																											
Alberta	195	2	157	141	1	49	72	—	16	83	1	15	—	—	—	—	—	—	—	—	—	491	4	237	50	—	—
Brit. Columbia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ecole	129	—	—	80	—	—	61	—	—	60	—	—	45	—	—	—	—	—	—	—	—	375	—	—	46	—	—
McGill	144	6	168	96	2	94	131	4	61	99	6	22	4	3	—	—	—	—	—	—	—	474	21	345	—	—	—
New Brunswick	56	—	67	44	—	26	27	1	7	30	—	6	—	—	—	—	—	—	—	—	—	157	2	105	29	—	—
Nova Scotia	—	—	—	—	—	—	72	—	9	36	—	11	—	—	—	—	—	2	—	—	—	108	—	22	31	—	—
Queen's	108	1	241	118	—	112	112	—	51	85	1	22	—	—	—	—	—	—	—	—	—	423	2	426	96	—	—
Saskatchewan	478	1	263	181	—	66	115	1	32	99	1	19	—	—	—	1	—	1	—	—	—	874	3	381	62	—	—
Toronto	—	—	418	255	6	336	181	6	125	241	2	51	2	1	7	—	—	—	—	—	—	679	15	937	216	3	1
Canadian Schools	1110	10	1314	915	9	683	771	12	301	733	11	146	51	4	7	1	1	3	—	—	—	3581	47	2453	530	3	1
U. S. Schools	23304	547	8604	7393	367	3488	4591	240	1817	3073	111	897	82	5	19	281	11	192	6672	473	897	45396	1754	15915	4007	53	130
Grand Total (145 Inst.)	24414	557	9918	8308	376	4171	5362	252	2118	3806	122	1043	133	9	26	282	12	195	6672	473	897	48977	1801	18368	4537	56	131

Grand Total (145 Inst.)	24414	857	9918	8308	376	4171	5363	252	2118	3806	122	1043	133	9	26	283	12	195	6672	473	897	48977	1801	18368	4537	56	131

Enrollment of Graduate Civilian Engineering Students, as of November 5, 1945

Engineering Courses	Enrollment in Work for the Master's Degree															Enrollment in Work for the Doctor's Degree											
	Full-Time Resident Students			Part-Time Resident Students			Evening Students			Total			Masters Degrees Conferred in 1944–45			Part-Time Resident Students			Full-Time Resident Students			Evening Students			Total			Doctors Degree Conferred in 1944–45		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Aeronautical	69	—	—	20	—	—	52	1	5	141	1	5	22	—	—	4	—	—	3	—	—	12	1	—	19	1	—	4	—	—
Agricultural	4	—	2	6	—	—	—	—	—	10	—	2	1	—	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Architectural	3	1	2	6	1	—	—	—	—	9	2	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Ceramic	14	2	3	5	1	1	—	—	—	19	3	4	2	—	—	3	—	—	1	—	1	—	—	—	4	—	1	1	—	—
Chemical	219	2	28	111	—	8	340	8	11	670	10	47	90	—	8	42	—	1	28	1	2	49	—	1	119	1	4	24	—	6
Civil	142	—	18	70	1	2	75	—	7	287	1	27	47	—	2	15	—	—	7	—	1	4	—	—	26	—	1	10	—	—
Electrical	190	—	12	75	2	7	638	5	7	903	6	26	67	1	—	26	—	—	3	—	1	23	—	—	52	—	1	7	—	—
Industrial	31	—	4	1	—	—	99	—	4	131	1	8	24	—	—	5	—	—	11	1	—	2	—	—	18	1	—	—	—	—
Mechanical	183	2	14	84	—	1	132	4	3	399	6	18	73	1	2	21	—	1	9	—	—	—	—	—	30	—	1	12	—	—
Metallurgical	58	—	3	19	—	1	172	6	2	249	6	6	24	—	—	18	2	—	8	—	1	4	—	—	30	2	1	4	—	—
Mining	28	—	9	10	—	1	17	1	1	52	1	11	7	—	—	6	—	—	1	—	—	—	—	—	7	—	—	1	—	—
Unclassified	156	1	5	42	1	3	466	10	3	664	12	11	84	1	—	32	—	1	—	—	—	20	—	—	52	—	1	6	—	—
Totals	1097	8	100	446	6	24	1991	35	43	3534	49	167	442	3	12	173	2	3	71	2	6	114	1	1	358	5	10	70	—	6

Enrollment of Graduate Civilian Engineering Students, as of November 5, 1945—Continued

Engineering Courses	Enrollment in Work for the Master's Degree															Enrollment in Work for the Doctor's Degree											
	Full-Time Resident Students			Part-Time Resident Students			Evening Students			Total			Masters Degrees Conferred in 1944-45			Part-Time Resident Students			Full-Time Resident Students			Evening Students			Total			Doctors Degree Conferred in 1944-45		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Ala. Uni.	4	—	3	—	—	—	—	—	—	4	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ala. Poly.	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Alfred	2	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Arizona	3	—	2	—	—	—	—	—	—	3	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Brooklyn	5	—	1	—	—	—	396	8	18	401	8	19	18	—	—	—	—	—	2	—	1	57	—	1	59	—	2	2	—	—
Calif. Uni. So.	11	2	5	16	1	4	—	—	—	27	3	9	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Calif. Tech.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Calif. Uni.	35	—	—	12	—	—	—	—	—	47	—	—	—	—	—	8	—	—	3	—	—	—	—	—	11	—	—	—	—	—
Carnegie	15	—	—	3	—	—	71	2	1	89	2	1	11	—	—	3	—	—	5	—	—	1	—	—	9	—	—	4	—	—
Case	—	—	1	1	—	—	43	—	—	44	—	1	5	—	—	—	—	—	—	—	—	5	—	—	5	—	—	4	—	—
Catholic	1	—	—	10	—	—	—	—	—	11	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Cincinnati	—	—	—	6	—	1	—	—	—	6	—	1	7	—	—	9	—	1	—	—	—	—	—	—	9	—	1	3	—	—
Colo. Mines	3	—	2	—	—	—	—	—	—	3	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Colo. Uni.	8	—	2	11	—	3	53	—	—	72	—	5	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Columbia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cornell	—	—	—	42	1	—	—	—	—	42	1	—	—	—	—	12	—	—	—	—	—	—	—	—	12	—	—	—	—	—
Delaware	6	—	—	1	—	—	—	—	—	7	—	—	1	—	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Florida	4	—	—	—	—	—	—	—	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ga. Tech.	14	—	—	—	—	—	—	—	—	14	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Harvard	61	—	12	3	—	—	—	—	—	64	—	12	17	—	1	10	—	—	16	—	—	—	—	—	26	—	—	1	—	—
Ill. Tech.	6	—	1	42	1	—	258	3	1	306	4	2	6	—	—	11	—	—	—	—	—	20	—	—	31	—	—	2	—	—
Ill. Uni.	25	1	5	12	—	3	—	—	—	37	1	8	11	—	—	7	—	—	5	—	1	—	—	—	12	—	1	7	—	—

Enrollment of Graduate Civilian Engineering Students, as of November 5, 1945—Continued

Enrollment of Graduate Civilian Engineering Students, as of November 5, 1945—Continued

Engineering Courses	Enrollment in Work for the Master's Degree															Enrollment in Work for the Doctor's Degree												
	Full-Time Resident Students			Part-Time Resident Students			Evening Students			Total			Masters Degrees Conferred in 1944–45			Part-Time Resident Students			Full-Time Resident Students			Evening Students			Total			Doctors Degree Conferred in 1944–45		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Iowa St. Coll.	10	—	—	4	—	—	—	—	—	14	—	—	1	—	—	8	—	—	—	—	—	—	—	—	8	—	—	1	—	—
Iowa Uni.	11	—	3	—	—	—	—	—	—	11	—	3	2	—	—	—	—	—	3	—	1	—	—	—	3	—	1	—	—	—
J. Hopkins	19	—	—	14	—	—	2	—	—	35	—	—	2	—	—	1	—	—	3	—	—	—	—	—	4	—	—	—	—	—
Kans. St. Coll.	—	—	1	3	—	2	—	—	—	3	—	3	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Kans. Uni.	1	—	1	2	—	—	—	—	—	3	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Kentucky	2	1	—	—	—	—	—	—	—	2	1	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lafayette	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lehigh	2	—	—	4	—	—	—	—	—	6	—	—	1	—	—	1	—	—	1	—	—	—	—	—	2	—	—	1	—	—
Louisiana	4	—	—	—	—	—	—	—	—	4	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—
Louisville	19	—	—	—	—	—	—	—	—	19	—	—	11	—	3	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Maine	3	—	1	—	—	—	—	—	—	3	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Maryland	2	—	—	10	—	—	54	—	—	66	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mass. Inst. Tech.	465	—	—	—	—	—	—	—	—	465	—	—	131	3	—	—	—	—	—	—	—	—	—	—	—	—	—	13	—	—
Mich. St. Coll.	—	—	1	2	—	—	—	—	—	2	—	1	1	—	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Mich. M. & T.	1	—	3	—	—	—	—	—	—	1	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mich. Uni.	104	2	10	9	1	—	7	—	—	120	3	10	49	—	—	13	—	1	16	—	—	—	—	—	29	—	1	5	—	—
Minnesota	—	—	—	55	—	—	—	—	—	55	—	—	6	—	—	28	1	1	—	—	—	—	—	—	28	1	1	4	—	—
Mo. Mines	7	—	1	—	—	—	—	—	—	7	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mo. Uni.	1	—	—	—	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mont. St. Coll.	—	1	1	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mont. Mines	3	—	3	—	—	—	—	—	—	3	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nebraska	3	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Newark	—	—	—	—	—	—	63	3	2	63	3	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
N. Mex. Uni.	—	—	—	2	—	2	—	—	—	2	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Enrollment of Graduate Civilian Engineering Students, as of November 5, 1945—Continued

Engineering Courses	Enrollment in Work for the Master's Degree												Masters Degrees Conferred in 1944–45			Enrollment in Work for the Doctor's Degree												Doctors Degree Conferred in 1944–45		
	Full-Time Resident Students			Part-Time Resident Students			Evening Students			Total						Part-Time Resident Students			Full-Time Resident Students			Evening Students			Total					
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
N. Y. C. C.	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
New York Uni.	5	—	—	—	—	—	241	4	17	246	4	17	41	—	—	—	—	—	1	1	—	20	1	—	21	2	—	1	—	—
N. C. St. Coll.	3	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Northwestern	—	—	3	3	—	—	39	—	—	42	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ohio State	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Okla. A. & M.	—	—	1	1	—	—	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Okla. Uni.	1	—	1	—	—	—	—	—	—	1	—	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oregon	5	—	1	4	—	1	—	—	—	9	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pa. St. Coll.	9	—	2	27	2	1	—	—	—	36	2	3	8	—	—	12	1	—	—	—	—	—	—	—	12	1	—	3	—	—
Pennsylvania	3	—	—	—	—	—	86	—	—	89	—	—	2	—	—	10	—	—	—	—	—	—	—	—	10	—	—	—	—	—
Pittsburgh	5	—	—	—	—	—	297	—	—	302	—	—	24	—	—	—	—	—	—	—	—	11	—	—	11	—	—	2	—	—
Princeton	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Purdue	40	—	—	20	—	—	—	—	—	60	—	—	9	—	—	10	—	—	2	1	—	—	—	—	12	1	—	8	—	—
Rochester	—	—	—	5	—	—	—	—	—	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rutgers	2	—	1	—	—	—	—	—	—	2	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Stanford	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Stevens	—	—	—	—	—	—	329	14	4	329	14	4	44	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Syracuse	4	—	—	—	—	—	52	1	—	56	1	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tennessee	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Texas A. & M.	11	—	—	12	—	—	—	—	—	23	—	—	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Texas Uni.	26	—	9	9	—	1	—	—	—	35	—	10	8	—	8	8	—	—	1	—	—	—	—	—	9	—	—	6	—	6
Tulane	3	—	—	1	—	—	—	—	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tulsa	4	1	1	—	—	—	—	—	—	4	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Enrollment of Graduate Civilian Engineering Students, as of November 5, 1945—Continued

Enrollment of Graduate Civilian Engineering Students, as of November 5, 1945—Continued

Engineering Courses	Enrollment in Work for the Master's Degree															Enrollment in Work for the Doctor's Degree												
	Full-Time Resident Students			Part-Time Resident Students			Evening Students			Total			Masters Degrees Conferred in 1944–45			Part-Time Resident Students			Full-Time Resident Students			Evening Students			Total			Doctors Degree Conferred in 1944–45		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Utah Uni.	8	—	—	—	—	—	—	—	—	8	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Va. Poly.	14	—	11	4	—	—	—	—	—	18	—	11	1	—	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Wash. St. Coll.	2	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Wash. Uni.	13	1	1	14	—	—	—	—	—	27	1	1	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Wash U. (St. L.)	12	—	3	—	—	—	—	—	—	15	—	3	2	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—
W. Va. Uni.	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—
Wisconsin	1	—	—	18	—	5	—	—	—	19	—	5	4	—	—	9	—	—	—	—	—	—	—	—	9	—	—	—	—	—
Worcester	4	—	3	2	—	—	—	—	—	6	—	3	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Wyoming	2	—	2	—	—	—	—	—	—	2	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Yale	6	—	2	11	—	1	—	—	—	17	—	3	1	—	—	5	—	—	4	—	3	—	—	—	9	—	3	1	—	—
Total U. S. Schools	1044	8	100	396	6	24	1991	35	43	3431	49	167	435	3	12	169	2	3	65	2	6	114	1	1	348	5	10	69	—	—
Canadian Schools																														
Alberta	4	—	—	20	—	—	—	—	—	24	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
British Columbia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ecole Polytechnique	—	—	—	2	—	—	—	—	—	2	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Toronto	47	—	—	23	—	—	—	—	—	70	—	—	3	—	—	4	—	—	6	—	—	—	—	—	10	—	—	1	—	—
Saskatchewan	2	—	—	5	—	—	—	—	—	7	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total Canadian Schools	53	—	—	50	—	—	—	—	—	103	—	—	7	—	—	4	—	—	6	—	—	—	—	—	—	—	—	1	—	—
Total U. S. Schools	1044	8	100	396	6	24	1991	35	43	3431	49	167	435	3	12	169	2	3	65	2	6	114	1	1	348	5	10	69	—	6
Grand Total (76 Inst.)	1097	8	100	446	6	24	1991	35	43	3534	49	167	442	3	12	173	2	3	71	2	6	114	1	1	358	5	10	70	—	6